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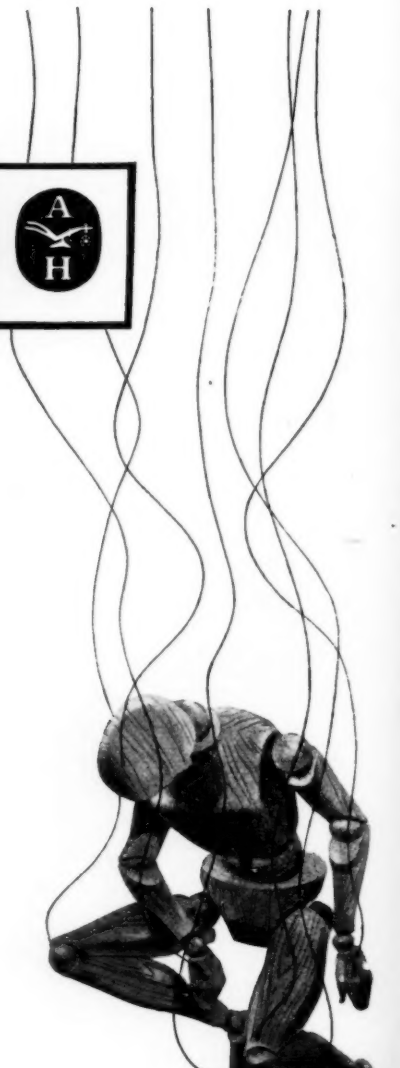

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BRITISH JOURNAL OF ANAESTHESIA

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EDITORIAL

SPINAL ANAESTHESIA

WE publish in this issue a paper on spinal anaesthesia by Dr. R. J. Stout. The popularity of spinal anaesthesia has waxed and waned ever since its introduction more than sixty years ago. Its present unpopularity in this country is easily understandable, but appears to be a local phenomenon, for according to the author of this paper "Surgeons working in hot climates believe that their patients fare better after spinal anaesthesia than after general anaesthesia". Moreover, in the United States impressionable series have been described (Dripps and Vandam, 1954; Sadove and Levin, 1954), in which the complications attributable to the anaesthesia were extremely rare or nonexistent. Only three years ago, a series of 37,391 spinal anaesthetics given to obstetrical patients was reported in which there was neither neurological complications nor maternal mortality (Macer, 1956).

Modern anaesthesia is largely based on the idea of using a number of drugs each having its own special function. Anaesthetists have achieved notable successes with this method, but other methods such as chloroform, ether, nitrous oxide and oxygen, spinal, local intravenous, have each and all been hailed as "the method of choice" by one enthusiast after another. It is only as experience is gained that one and all have been found to have undesirable side effects. To retain the good qualities of each method and eliminate the undesirable is the object of all new work, experiment and research.

An eminent anaesthesiologist from across the Atlantic, with great experience of spinal anaesthesia said, "After a death under spinal anaesthesia, the anaesthetist may often properly write his own name in the space on the certificate reserved for the cause of death." Another most distinguished anaesthesiologist from a lifetime of experience of American surgery said that at that time "About one patient in a thousand subject to surgical operations dies before leaving the theatre regardless of the drug used". He went on to suggest again that frequently it is the human element rather than the anaesthetic that is to blame. At the conclusion of a review on 1,000 cases of death associated with anaesthesia reported by a committee of the Association of Anaesthetists of Great Britain and Ireland it is stated that "In the great majority of the reports, however, there were departures from the accepted practice" (Edwards et al., 1956). A polite way of saying the fault probably lay with the administrator rather than with the technique. The conclusion from all this seems to be that we must maintain our efforts to improve anaesthetic training and education and this applies no matter what method is used.

Over the years we have learnt a lot about spinal anaesthesia. We have better drugs; we know that dilute solutions are safer than concentrated ones; we know how to sterilize ampoules; we appreciate that a gentle Trendelenburg position is better than a steep or reversed one, and that a spinal anaesthetic kills only by paralyzing respiration. The modern anaesthetist is now an expert in maintaining adequate pulmonary ventilation owing to his extensive practice on patients in apnoea and this must improve the technique and safety of spinal anaesthesia.

The fear of litigation must not permit us to be deprived of this useful technique in those circumstances where it is indicated.

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ELECTROCARDIOGRAPHIC STUDIES DURING THE INHALATION OF 30 PER CENT CARBON DIOXIDE IN MAN

BY

L. McARDLE

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CARBON DIOXIDE inhalation was first used for the treatment of psychosis by Loevenhart, Lorenz and Waters in 1926, but the results were not encouraging. Meduna (1943), introduced 30 per cent carbon dioxide inhalation as a treatment for psychoneurosis, and claimed good results, particularly in cases of stammering. Since its introduction, this treatment has been used in several thousand cases by Meduna and his associates.

The human electrocardiogram during 30 per cent carbon dioxide inhalation has been studied by McDonald and Simonson (1953), and these authors describe some disturbance of auricular or ventricular activity in 12 of 17 patients investigated. Auricular and ventricular extrasystoles, P wave inversion, alteration in the T wave voltage, together with auricular and supraventricular tachycardia were all found.

In the psychiatric department of this hospital, 30 per cent carbon dioxide in oxygen inhalation is in routine use for suitable cases and appears to be clinically safe. The administration of such treatment presented an opportunity to study the response of the human cardiovascular system when subjected to a brief but very acute form of respiratory acidosis.

The behaviour of the blood flow through the limbs was investigated (McArdle, Roddie, Shepherd and Whelan, 1957), and the presence of marked vasoconstriction in the forearm and calf, associated with a rise in arterial blood pressure was demonstrated. This response was greatly modified when the patient was deeply anaesthetized, and it would appear that sympathetic stimulation by carbon dioxide is responsible for the changes in limb blood flow (McArdle and Roddie, 1958).

In the present paper electrocardiographic studies were carried out in 8 patients (4 males and 4 females) before, during and after 30 per cent carbon dioxide inhalation. The results obtained were not in complete agreement with those of McDonald and Simonson. Evidence of delayed conduction and numerous auricular extrasystoles were observed but no ventricular extrasystoles were seen. Auricular tachycardia, which occurred in 2 subjects on one occasion each, was the only disturbance of rhythm encountered.

METHODS

A mixture of approximately 30 per cent carbon dioxide and 70 per cent oxygen was administered by means of a breathing bag and tightly fitting facepiece from a stock cylinder, via a reducing valve and flowmeter, with the patient lying supine on a couch or trolley. Normally, observations were made during 3 treatments in each of the 8 patients. Additional recordings were made in the 2 subjects in which auricular tachycardia was observed. Treatment was commenced with 10 or 15 respirations of the mixture and the patient's clinical response noted. On subsequent occasions the number of respirations was increased gradually until the number required to produce narcosis was reached (Meduna, 1943). When carbon dioxide inhalation was complete the mask was removed and the patient allowed to breath room air again. The majority of patients required 35 to 45 respirations of 30 per cent carbon dioxide to produce narcosis, and this was administered in all treatments after the gradual introduction described. Electrocardiographic studies were carried out only after the treatment had been standardized in this manner.

The majority of the electrocardiographic records were taken with an Elmquist portable, though several were made with a standard hospital model Cambridge machine.

A general physical examination was carried out on all patients before treatment, and a nine-lead electrocardiogram (I, II, III, aVF, aVL, aVR, V2, V4, V6) was also recorded at this time. These records were examined to exclude cardiac abnormality and to determine the electrical axis for future reference. As it was only possible to record one lead during treatment and recovery, lead II was chosen as the most suitable. Short runs of leads I, II, and III, were made before the treatment under investigation. Lead II was then recorded throughout the period of inhalation of carbon dioxide and for about 2 minutes of the recovery period, when the inhalation was stopped and the patient breathed room air again.

Arterial Blood Pressure.

Records of systolic and diastolic blood pressures were obtained during carbon dioxide inhalation and recovery. These were at first made using a sphygmomanometer, but subsequently were directly recorded from a needle in the brachial artery by a capacitance manometer. The results obtained by both methods were in complete agreement.

pH Estimations.

The pH of venous blood was determined in a number of patients using a Cambridge pH meter. The blood samples were drawn into nylon syringes which had been rinsed with heparin. The syringes were sealed with caps made from soldered needle hubs, and stored in ice until the pH measurements were made.

Respiratory Records.

These were recorded using two stethographs, one round the chest and one round the abdomen, connected to a single volume recorder from which tracings were obtained on a kymograph.

RESULTS

When 30 per cent carbon dioxide was inhaled, marked respiratory stimulation commenced after about 5 respirations. Increase in depth was more pronounced than increase in rate; in some cases this became extreme, and a gasping type of respiratory pattern occurred. Marked muscular tremor and profuse sweating were commonly present. Salivation was pronounced in many patients.

Cardiac Rate.

There was great variation in the response of the cardiac rate to 30 per cent carbon dioxide inhalation, and no consistent change was found. This is to be expected when it is considered how many factors are involved. Apprehension, the rise in arterial blood pressure, mechanical effects of hyperventilation, stimulation of chemoreceptors, the direct effect of the carbon dioxide on the central nervous system, and the cardiac conducting mechanism, must all exert an influence on the cardiac rate. Table I shows the response to a typical treatment in each patient.

TABLE I

The effect of 30 per cent carbon dioxide inhalation on the cardiac rate, PR and QT intervals.

	Before CO_2			During CO_2			After CO_2		
Subject	Cardiac rate per min	PR secs	QT secs	Cardiac rate per min	PR secs	QT secs	Cardiac rate per min	PR secs	QT secs
1	86	0.14	0.34	100	0.17	0.37	110	0.14	0.3
2	86	0.14	0.32	83	0.18	0.36	100	0.15	0.32
3	91	0.16	0.32	97	0.2	0.37	91	0.14	0.33
4	86	0.1	0.3	86	0.14	0.36	86	0.1	0.34
5	115	0.14	0.28	130	0.16	0.3	97	0.15	0.28
6	83	0.16	0.32	100	0.18	0.35	86	0.15	0.33
7	85	0.16	0.34	100	0.16	0.4	100	0.15	0.34
8	75	0.15	0.34	88	0.16	0.38	85	0.14	0.32

Arterial Blood Pressure.

The inhalation of 30 per cent carbon dioxide produced a marked and progressive rise in both systolic and diastolic blood pressure values. When the mask was removed and the patient allowed to breathe room air, the systolic and diastolic blood pressures returned to resting levels again. In several cases the rise in arterial blood pressure was great enough to be considered a potential hazard in the presence of degenerative vascular conditions.

P Wave.

Increased P wave voltage was encountered during treatment and early recovery in the majority of cases, and the wave presented a peaked appearance. Low or inverted P waves were observed in 12 records from 5 patients in association with abnormal complexes. In 3 records the P wave voltage was not increased but the contour changed and it became peaked as in the other cases. Prominent S waves were often seen in conjunction with the increased P waves.

TABLE II

The effect of 30 per cent carbon dioxide inhalation on the pH of venous blood

Subject	pH before CO_2	pH during CO_2	pH after CO_2
1	7.4	7.12	7.38
2	7.31	7.29 7.16	—
3	7.48	7.13	7.3
4	7.42	7.22 7.12	7.4
5	7.4	7.24 7.15	7.4

pH Results.

A severe and progressive acidosis was produced during 30 per cent carbon dioxide inhalation (table II). When the carbon dioxide inhalation was stopped the pH values returned very rapidly to normal values again.

ELECTROCARDIOGRAMS

Complexes.

Of 30 electrocardiographic records obtained, 18 showed no abnormal complexes. Three of the patients studied showed no abnormal complexes in any of their recordings. Auricular extrasystoles were present in 12 records obtained from the other 5 patients (fig. 1) and could be identified during treatment or recovery or both. In several, extrasystoles occurred only during recovery when the carbon dioxide treatment was stopped and the patient breathed room air again.

Disturbances of Rhythm.

In 2 patients an abnormal rhythm occurred towards the end of treatment and during the first 45 seconds of the recovery period. This consisted of short runs of auricular tachycardia with scattered auricular extrasystoles (fig. 2). No such abnormal rhythm was observed during the other treatments studied in these patients.

T Wave.

A spiked T wave with a broad base was commonly present during carbon dioxide inhalation and increased T wave voltage was present in all but one of the records. In one of two records which showed the presence of auricular tachycardia the T wave voltage was very low.

ST Segment.

There were isolated instances of ST segment elevation in two treatments on one subject. In one of these records extrasystoles were present. All other records in all patients showed normal ST segments.

PR Interval.

This showed some slight increase in most records during treatment and early recovery (table I). In many cases the interval was difficult to measure due to absence or distortion of the P wave.

QRS.

Some slight increase was present in the QRS interval in all cases during treatment and early recovery.

FIG. 1
Upper tracing shows normal complexes at beginning of 30 per cent CO_2 inhalation. Lower tracing shows presence of auricular extrasystoles occurring towards the end of inhalation (lead II).

FIG. 2
Paroxysmal auricular tachycardia occurring during 30 per cent CO_2 inhalation. Lower tracing shows one extrasystole. The P and T wave voltage is increased and the PR and QT intervals are prolonged (Lead II).

QT Interval.

There was a marked increase in the QT interval relative to cycle length in all cases during treatment (table I). This was the most definite and consistent finding in the whole series. Figure 3 shows how the inhalation of 30 per cent carbon dioxide is accompanied by a marked increase in the QT interval, which returns to levels, normal for the cycle length, after inhalation ceases. Here the observed QT interval is graphed along with the upper limits of normal for the cycle length, which were obtained from the table by Ashman and Hull (1945). This table derived from observations on several thousand normal subjects can be applied relative to age and sex.

DISCUSSION

Inhalation of 30 per cent carbon dioxide produces hyperventilation, severe acidosis and a marked rise in arterial blood pressure. The procedure is unpleasant, and in the conscious untrained subject is associated with a considerable degree of mental stress. Each of these factors is capable of producing changes in the electrocardiogram and it is difficult to decide the relative importance of each.

Hyperventilation.

True hyperventilation in air is accompanied by a low P_{CO_2} and alkalosis, and so is not directly comparable to the circumstances of the present investigation. Since inhalation of 30 per cent carbon dioxide causes marked hyperpnoea the mechanical effects of the greatly increased respiratory movements must be considered, for these can cause alterations in intrathoracic pressures, displacement of the electrical axis of the heart, and may initiate reflexes from stretch receptors in the chest. Reflexes during deep breathing have been shown to cause extrasystoles. Ventricular and auricular extrasystoles as well as auricular flutter and fibrillation have been repeatedly described (Stokes, 1910; Smith and Moody, 1923; Burak and Scherf, 1933). Evans (1951) investigated the effect of deep inbreathing in 200 healthy adults and describes the frequent occurrence of extrasystoles and, in one case, of paroxysmal tachycardia. However, unless carbon dioxide elimination is prevented, hypocapnia must be considered as a possible factor in the production of electrocardiographic changes occurring with deep breathing. It is difficult therefore to decide the importance to be attached to the mechanical effects of hyperventilation in the production of electrocardiographic changes in the present series.

Acidosis.

The acidosis produced by the inhalation of 30 per cent carbon dioxide is severe and progressive and low pH values were commonly encountered (table II). Gibbs and Gibbs, quoted by Meduna (1950), have shown changes in arterial blood pH from a level of 7.37 to 6.96 after 20 to 35 breaths of 30 per cent carbon dioxide, with an almost immediate return to normal after carbon dioxide inhalation ceases.

Prolongation of the QT interval, a consistent finding in the present investigation, commonly accompanies altered blood calcium or potassium levels (Bellet and Steiger, 1950). Potassium intoxication, which is associated with acidosis, produces alterations in the electrocardiogram similar to those found in the present series of cases. There is an increase in the T wave voltage and the wave shows a peaked, tent-like character, the PR and QT intervals are increased and the QRS complex is also prolonged (Bland, 1956). Ectopic arrhythmias too, have been reported in patients with hyperkalaemia (Somerville, 1951). Respiratory acidosis was studied in the dog during diffusion respiration and with carbon dioxide inhalation, and increase in T wave voltage, QRS voltage and prolongation of the PR interval with slowing of the heart rate noted (Brown and Millar, 1952; Whitehead et al., 1949; Parry, 1949). Using 30 per cent carbon dioxide inhalation in dogs, Brown and Millar (1952) found occasional ventricular extrasystoles and increased T wave voltage during inhalation, but found that ventricular arrythmias, frequently leading to death, occurred on changing from carbon dioxide back to atmospheric air. In the present series, auricular extrasystoles, and, in one patient, bouts of auricular tachycardia occurred after carbon dioxide inhalation ceased, no abnormal rhythms or complexes being present during the inhalation. It is considered (Brown and Millar, 1952) that the sudden shift in pH back to normal is responsible for this. It would appear that changes in the T wave and PR, QRS, and QT intervals encountered in these cases could be ex-

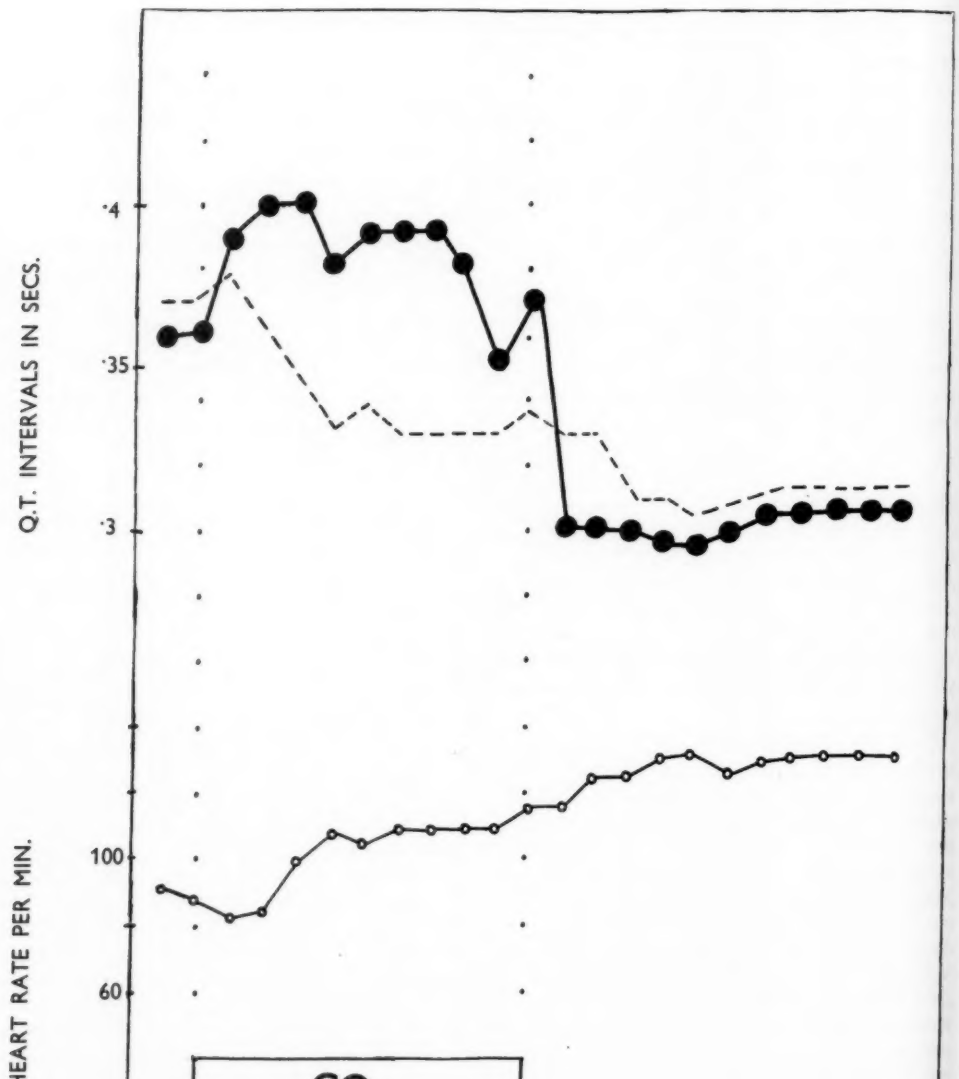

FIG. 3

Prolongation of the QT interval produced by 30 per cent CO_2 inhalation.

●——● Measured QT interval.

– – – – – Upper limits of normal QT for cycle length.

o——o Cardiac rate.

plained on the basis of ionic changes occurring during the severe acidosis.

Hypertension.

The presence of extrasystoles in patients with hypertension is described by many authors (Peel, 1928; Koppang, 1924; Flaxman, 1940). Hegglin and Halzman (1937) described the appearance of extrasystoles during hypertensive crises in patients with phaeochromocytoma, but it is considered (Scherf and Schott, 1953) that it is not the hypertension of itself, but the circulating pressor amines adrenaline and noradrenaline which are responsible for their production. Dunér (1955) has found that hypercapnia causes an increased release of adrenaline and noradrenaline. Moe et al. (1949) found that a sudden increase in peripheral resistance due to vasoconstriction is badly tolerated by heart muscle and can bring on ventricular tachycardia or even fibrillation. Intense vasoconstriction in muscle vessels occurs during 30 per cent carbon dioxide inhalation (McArdle, Roddie, Shepherd and Whelan, 1957). Undoubtedly the rise in arterial blood pressure produced by the inhalation of 30 per cent carbon dioxide, which is at times extreme and associated with vasoconstriction in the limbs, is a likely factor in the production of the extrasystoles seen in these cases.

Mental Stress.

Alterations in the P wave are commonly of emotional origin (Burch and Winsor, 1950), and apprehension or fear could produce the increase in P wave voltage encountered. However, inverted or absent P waves imply that the wave of excitation follows an abnormal pathway through the auricles as in auricular or nodal premature contractions (Burch and Winsor, 1950). Anxiety and fear can produce extrasystoles (Katz, Winton and Megibow, 1947). Fleisch (1933) recorded extrasystoles in two-thirds of subjects investigated during an examination, and Millar and McLean (1941) describe four instances of extrasystoles occurring during severe inner conflicts. It is of importance, also, that nervous factors can increase the incidence of extrasystoles produced by other causes, e.g. hypertension (Scherf and Schott, 1953). Though the rise in arterial blood pressure and hyperventilation together with fear or anxiety on the part of the patient could conceivably produce extrasystoles and alterations in the P wave, the changes in the T wave and intervals suggest a state of ionic imbalance within the myocardium resulting from the severe acidosis. It appears likely, however, that the tolerance of well-oxygenated cardiac muscle to this is considerable, since no serious disturbances of rhythm were encountered in the whole series.

Anaesthesia and Carbon Dioxide accumulation.

Cardiac irregularities under anaesthesia have been reported by many authors. The work of McDowall (1938), Meek (1940), Robbins (1945) and Johnstone (1950), suggest the importance of carbon dioxide accumulation as a factor. That carbon dioxide accumulation is common during general anaesthesia is undoubtedly true. Many factors such as the respiratory depressant action of anaesthetic agents (Dripps and Dumke, 1943), the increased use of muscle relaxants (Churchill-Davidson, 1958), the inefficiency of artificial ventilation (Gordon et al., 1951), and the increase in respiratory deadspace (Severinghaus and Stupfel, 1955; Pask, 1958), are responsible. Since most of these factors favour the production of hypoxia, it seems likely that disturbances of cardiac rhythm which occur will be aggravated by this, for severe hypoxia can itself produce a condition resembling fibrillation in the mammalian heart (Schwartz, 1949). Autonomic imbalance due to the anaesthetic agent used may produce cardiac irregularities, when a reflex is initiated by traction on a viscus (Wakefield, 1947; Maher et al., 1934) or from irritation of the glottis (Burstein et al., 1950). It is possible, therefore, that carbon dioxide accumulation under anaesthesia could be productive of more serious disturbances than were encountered in the present series, in which the acidosis, though very severe, was of short duration and uncomplicated by hypoxia or other factors.

SUMMARY

Electrocardiographic studies were made in 8 patients before, during, and after inhalation of 30 per cent carbon dioxide in oxygen for periods from 1 to 2 minutes. The inhalation caused hypertension and hyperpnoea and a marked fall in the pH of venous blood.

In spite of the severity of the respiratory acidosis, auricular extrasystoles were the only abnormal complexes seen, and were observed in 12

records from 5 of the 8 patients. No serious disturbances of rhythm were encountered. Periods of paroxysmal tachycardia were observed in 2 patients on one occasion each.

Increase in the PR, QRS and QT intervals suggested delayed conduction within the myocardium, and was considered to be a direct effect of the acidosis.

It is considered that the absence of hypoxia and other complicating factors distinguish the dangers of inhaling carbon dioxide in oxygen from carbon dioxide accumulation occurring during anaesthesia. Provided that patients free from cardiovascular disease are selected, carbon dioxide in oxygen can be administered as a therapeutic procedure without serious disturbance to cardiac function.

ACKNOWLEDGMENTS

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NEWS FROM THE FACULTY OF ANAESTHETISTS OF THE ROYAL COLLEGE OF SURGEONS

Honorary Fellowship in the Faculty of Anaesthetists. The Council of the College, acting on the recommendation of the Board of Faculty, has elected the following to the Honorary Fellowship in the Faculty:

Harold Randall Griffiths
Ashley Skeffington Daly.

Fellowship in the Faculty by Election. The Council of the College, acting on the recommendation of the Board of Faculty, has elected the following to the Fellowship in the Faculty:

Robert Henry Palmer Fitzpatrick
Alexandre Goldblat
Torsten Gordh
Geoffrey Arthur Haydock
Eric Nilsson.

Joseph Clover Lecture. Dr. J. A. Lee, F.F.A.R.C.S., has been appointed to give the Joseph Clover Lecture in March 1960, in place of Dr. H. J. Brennan, who has resigned for reasons of health.

Nuffield Prize. Dr. Sylvia Lock Seung Hui, M.B., B.S., of the University of Hong Kong, has been awarded the Nuffield Prize, having obtained the highest marks in the Primary Examination for the F.F.A.R.C.S. held in December 1958.

Adviser in Postgraduate Studies. Dr. W. D. Wylie, F.F.A.R.C.S., has been appointed Faculty Adviser in Postgraduate Studies. He will be pleased to advise, and arrange instruction for, any postgraduates studying anaesthetics in this country.

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GENERAL ANAESTHESIA FOR OPERATIVE OBSTETRICS

With Special Reference to the use of Thiopentone and Suxamethonium

BY

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IT is generally agreed that for obstetric procedures, anaesthesia not only causes particular anxieties for anaesthetist and obstetrician, but embodies inherent dangers for the mother and child.

In this unit different methods of general anaesthesia have been studied with these considerations in mind. Following an assessment and comparison of methods in an initial series of 264 patients, a technique based on thiopentone, nitrous oxide, and suxamethonium has now been adopted for all operative obstetric procedures.

In this paper the results of these comparisons are presented and discussed. Furthermore, in 600 patients anaesthetized by the adopted technique, the results have been analyzed and are presented and discussed in detail.

MATERIAL

All the subjects investigated in this series (704) were in-patients in the obstetric unit, which conducts 2,300–2,600 deliveries annually, of which 16–20 per cent require anaesthesia during the course of their labour.

A selected anaesthetic staff, with particular interest and training in obstetric anaesthetic requirements, forms a continuous 24-hour cover to the unit, and together with the obstetric personnel is responsible for the analgesia and anaesthesia of these patients.

Details are recorded of the pre-operative analgesia, the method and course of anaesthesia, and particularly the state of the infant at birth. The infant's breathing and crying times are observed and recorded accurately by a stop-watch, the breathing time being taken as the interval between delivery and onset of regular respirations. The recording of these observations is facilitated by the use of a special punch-card already described (Hodges, 1958a, 1959).

METHOD

The investigations extended over three years and the patients were divided into two groups (see table I). In the first group of 264 patients several different methods of anaesthesia were used and the results compared. The anaesthetists using these techniques had special experience, and were indeed advocates, of the methods used. The second group of 600 patients consisted of those on whom was used the technique based on thiopentone-suxamethonium-nitrous oxide. Six patients on whom insufficient observations were recorded were excluded.

Certain considerations were common to both groups. Pre-operative analgesia was adequate but minimal. Pethidine in doses of 50–100 mg was given according to generally accepted principles, and was combined with nalorphine and levallorphan in some later patients. In a few instances chlorpromazine was used in the course of labour, but these cases have been excluded from consideration here, having been reported separately (Hodges and Bennett, 1959). Nitrous oxide and air, or trichloroethylene was administered as indicated for maternal distress in the later stages, but nitrous oxide was withheld if foetal distress occurred, oxygen being administered instead.

The techniques used in the comparisons are listed in table II. All patients were premedicated with atropine 1/100 grain (0.65 mg) either intramuscularly or intravenously at the time the anaesthetist was called. Maternity beds were not used for any general anaesthetic case, the patient being

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TABLE I

	Techniques based on thiopentone-suxamethonium-nitrous-oxide		Other techniques		
	Caesarean section	Forceps delivery	Caesarean section	Forceps delivery	Totals
No. of patients during period in which comparisons were made	65	114	30	55	264 (Group I)
No. of patients during subsequent period	199	222	3	16	245
Totals	264	336	33	71	704
	600 (Group II)				

TABLE II

The different techniques of general anaesthesia used in the comparisons made in 264 patients

Technique 1
Thiopentone, suxamethonium, intubation and maintenance with nitrous oxide and oxygen. Additional suxamethonium to facilitate controlled respirations, and to prevent reflex movement. No other agent before delivery.

Technique 2
As in technique 1, but with the addition of trichloroethylene (Trilene) before delivery of infant.

Technique 3
Thiopentone followed by maintenance with cyclopropane and oxygen. Intubation when indicated, and addition of d-tubocurarine in all cases of abdominal section.

Technique 4
Nitrous oxide oxygen-ether sequence, with or without the addition of thiopentone for induction.

anaesthetized in an obstetric theatre on a standard operating table which could be easily tilted in either direction at the anaesthetist's control.

In the technique that we have now adopted routinely, anaesthesia is induced in the steep head-up tilt with the rapid intravenous injection of 5 per cent thiopentone (150–200 mg), and is followed at a 10–20 second interval by the administration of 50 mg of suxamethonium through the same needle (see plate I). Oxygen is then administered by mask, and if the respirations are depressed, assisted or controlled inflation is commenced. When the muscle fasciculations have been noted and the jaw is completely relaxed, rapid intubation is carried out with a cuffed endotracheal tube.

The patient is usually ready for intubation within 60 seconds of induction, but in exceptional cases where the initial dose of suxamethonium is inadequate further suxamethonium is administered before laryngoscopy is attempted. Special precautions already outlined may be needed in those patients who have previously received prolonged infusions of posterior pituitary extract (Pitocin) (Hodges, 1958a, b; Hodges et al., 1959).

Following intubation, controlled respiration is instituted on a semi-open circuit without absorption with nitrous-oxide (60–70 per cent) in oxygen, and small increments of suxamethonium are added, as necessary, to facilitate ventilation or to control reflex movements of the patient. No particular attempt is made to restore spontaneous respiration before delivery. Immediately prior to delivery 100 per cent oxygen is administered, and after the umbilical cord is clamped, anaesthesia is deepened by the addition of thiopentone, trichloroethylene, or other agent as desired. During the initial procedure, a close watch is kept on the maternal pulse, and on isolated occasions a tendency to bradycardia has been treated with small doses of intravenous atropine.

During the comparison of results certain criteria were adopted in order to classify the state of the infant at birth. Four grades of infant state were recognized in this classification (see table V). Patients in whom intra-uterine death of the foetus

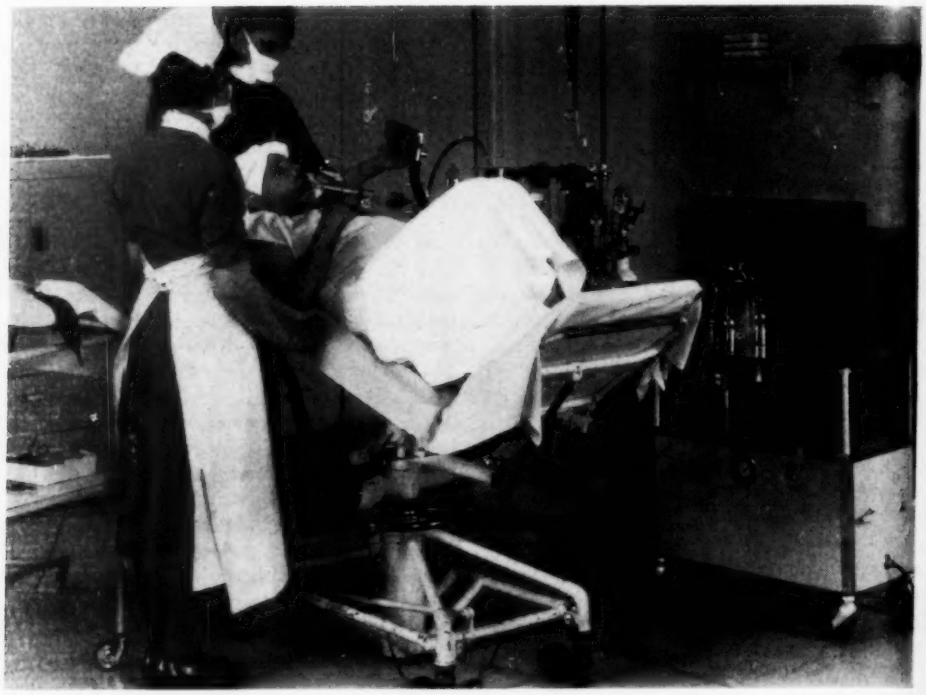

PLATE I
Showing induction of anaesthesia in the head-up position.

had been confirmed pre-operatively were excluded.

RESULTS

Group I. Comparison of different anaesthetic techniques.

Table III shows an analysis of the obstetric procedures for which anaesthesia was required during the period over which comparisons were made, and the incidence of foetal distress in these patients. Table IV shows the incidence of anaesthetic techniques used during the same period.

Table VI shows the incidence of those infants classified as fully active (see table V) in the anaesthetic technique used in the 264 patients subjected to Caesarean section and forceps delivery, and also the same incidence in the 95 patients subjected to Caesarean section alone.

It will be seen that of those patients receiving technique 1, 64 per cent of the whole series, and 62 per cent of the Caesarean sections were delivered of fully active infants, whereas of those patients receiving technique 4, 43 per cent and 12 per cent were the comparable figures. The techniques 2 and 3 occupy intermediate positions and it will be noted that the addition of trichloroethylene to the thiopentone-suxamethonium-nitrous oxide technique appears to diminish the number of fully active infants delivered.

Table VII shows the incidence, in each of the four anaesthetic techniques used, of foetal distress pre-operatively and immediate neonatal depression in 95 patients delivered by Caesarean section.

It will be seen that the highest incidence of foetal depression occurs in those patients who received ether in the technique, and the lowest incidence in those who received the thiopentone-suxamethonium-nitrous oxide sequence. Again it appears that the addition of trichloroethylene to

TABLE III

The analysis of obstetric procedures and incidence of foetal distress in 264 patients

		Incidence of foetal distress	
Caesarean section (95 patients)	18 Elective 16 Antepartum haemorrhage 13 Maternal distress 8 Pre-eclamptic toxaemia 6 Delay 18 Spontaneous foetal distress 16 Foetal distress associated with other factors	36%	
Manipulations and mid-cavity forceps delivery (78 patients)	17 Delay 25 Delay and malpresentation 6 Maternal distress 2 Toxaemia 2 Failed forceps (domiciliary) 4 Spontaneous foetal distress 22 Foetal distress associated with other factors	33%	41%
Outlet forceps delivery (91 patients)	32 Delay 5 Delay and malpresentation 6 Maternal distress 1 Toxaemia 25 Spontaneous foetal distress 22 Foetal distress associated with other factors	52%	

TABLE IV

The percentage incidence of anaesthetic techniques used in 264 patients

Technique	1	2	3	4	Other
No. of patients (%)	43.5	19.0	19.5	14.5	3.5

TABLE V

Grade 1

Fully active. All the infants in whom regular breathing and active crying was established within 60 seconds of delivery.

Grade 2

Active but sleepy. All the infants in whom regular respirations were established within 60 seconds and in whom active crying and movement was established in from 1 to 5 minutes.

Grade 3

Active slowly. All the infants who neither breathed regularly nor cried actively within 60 seconds, but who nevertheless caused no anxiety and were fully active within 5 minutes.

Grade 4

Depressed. All the infants who were not fully active in every respect within 5 minutes of delivery.

TABLE VI

The incidence of fully active infants delivered following each of the four anaesthetic techniques† (264 patients—Caesarean section and forceps delivery)*

Technique	1	2	3	4
Percentage of fully active infants delivered in whole series	64	59	56	43
Percentage of fully active infants delivered in Caesarean section only	62	44	40	12

*See Table V—grade 1. † See table II.

TABLE VII

The incidence of depressed infants and pre-operative foetal distress in each of the four anaesthetic techniques† (95 patients undergoing Caesarean section)*

Technique:	1	2	3	4
Percentage of infants not fully active in all respects within 5 minutes of delivery	24	32	31	75
As above but including only those patients with pre-operative foetal distress	26	62	80	66
Incidence of pre-operative foetal distress in each group	41	32	23	37

*See Table V—grade 4. † See table II.

this latter technique produces less satisfactory results, particularly when pre-operative foetal distress is present. Table VII also shows that when foetal distress is present a higher incidence of post-delivery depression was found following the cyclopropane (d-tubocurarine) technique (No. 3) than following the other techniques in this series.

In order to include in the comparison the total number of infants in all the grades classified, the breathing and crying times were considered in relationship to the technique used. For breathing time the interval between delivery and the maintenance of regular spontaneous respirations was recorded to the nearest quarter minute. Figure 1 shows this relationship and it will be apparent that the infants delivered following technique 1 have a shorter breathing and crying time than those following any other technique, and that furthermore the difference between those who received trichloroethylene and those who did not (techniques 1 and 2) is again apparent. The same distribution is shown when those patients who received sedation within the previous 4½ hours are excluded.

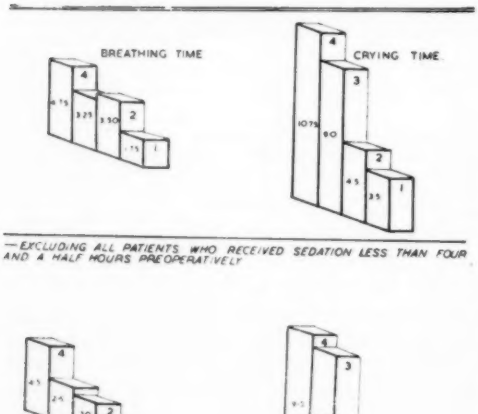

FIG. 1

Breathing and crying time in infant delivered by Caesarean section—under various anaesthetic techniques—times to nearest quarter minute (92 patients).

Group II. Analysis of infant state at birth in 600 patients anaesthetized by a technique based on thiopentone-suxamethonium-nitrous oxide.

In the majority of the later patients in this group who were anaesthetized for either Caesarean section or forceps delivery the interval between the intravenous thiopentone administration and the delivery of the child was also determined accurately (induction-delivery interval). Figure 2 shows the relationship, in 523 patients, between these two factors. It will be noted that all the induction delivery intervals exceeding 12 minutes have been grouped together for simplification. Thirteen stillbirths (see table VIII) have been excluded as have 2 infants with severe haemolytic disease whose breathing time exceeded 10 minutes.

Of the 50 infants whose breathing time was 5 minutes or longer, 41 (82 per cent) had an induction-delivery interval of from 4 to 10 minutes, and 7 (14 per cent) had an induction-delivery interval of more than 10 minutes. The shortest mean breathing time occurred in those infants delivered within 4 minutes of the induction of anaesthesia, and regular breathing was established in all but 2 of these infants within 5 minutes.

Table VIII lists the 13 stillbirths that occurred in the patients anaesthetized by thiopentone-suxamethonium and nitrous oxide. Five of these foetuses showed postmortem changes and in all but one of the 13 instances intra-uterine death was suspected pre-operatively. In this instance severe foetal distress had been present and the foetal heart had been failing during the 10 minutes immediately preceding operation. Resuscitative measures resulted in restarting the heart temporarily. Resuscitative measures were undertaken in one other instance without success.

Nineteen neonatal deaths occurred in this same series: 5 followed on from depression at birth, 1 associated with a gross tentorial tear, 2 with severe haemolytic disease, 1 neonatal pneumonia, and 1 congenital heart disease; in the remaining 14 (see table IX) the condition at delivery did not give rise to anxiety, and in 12 instances the cause of death was nonanaesthetic. One remote death (case 13) could not be explained, and another

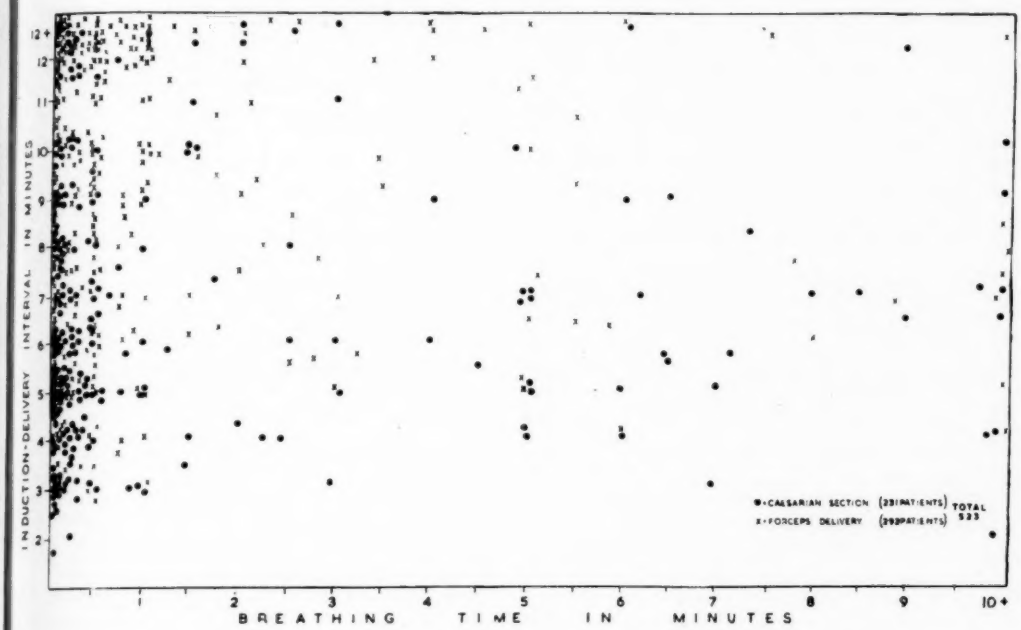
INDUCTION-DELIVERY INTERVAL IN MINUTES
BREATHING TIME IN MINUTES
•=CAESARIAN SECTION (231PATIENTS) TOTAL
×=FORCEPS DELIVERY (292PATIENTS) 523

FIG. 2

The relationship between the induction-delivery interval and the infant breathing time in patients delivered by forceps or abdominal section conducted under thiopentone-suxamethonium-relaxant technique.

(case 9) could not be dissociated from anaesthesia in view of time factor and other negative findings.

There were 52 infants (8.7 per cent) in the series who were not considered fully active at 5 minutes after delivery excluding the 5 neonatal deaths already noted. Routine resuscitative measures consisting of tracheopharyngeal toilet followed by intratracheal oxygen, resulted in the complete recovery within 10 minutes of all but 11 infants (1.8 per cent). One infant with severe haemolytic disease needed to be maintained on intermittent positive pressure inflation for 70 minutes but thereafter recovered uneventfully with routine treatment. One infant remained spastic, although breathing had been established within 6 minutes. The remaining 9 infants, who had all been severely distressed pre-operatively, recovered completely after maintenance for a further 1–10 minutes with endotracheal oxygen.

In this series there was 1 maternal death which resulted from acute heart failure in the second week postoperatively. The patient had severe mitral stenosis and had undergone emergency Caesarean section without incident.

DISCUSSION

Special Considerations of Obstetric Anaesthesia

Obstetric patients, often distressed, sometimes exhausted, may be ill-prepared for anaesthesia, and they are not infrequently suffering from shock and blood loss. During anaesthesia the anaesthetist is burdened with the added responsibility of two patients, one of whom is, on occasions, already distressed and hypoxic, and whose respiratory centre may be profoundly influenced and still further depressed by any medication administered to the mother. The particular problem encountered in the obstetric department may

TABLE VIII

Details relating to stillbirths from patients anaesthetized with thiopentone-suxamethonium sequence

	History	Procedure*	Comments
1	Intra-uterine death suspected prior to admission	F.D.	Stillborn child with early postmortem changes—calcified placenta
2	Foetal heart slowed considerably and failing 10 mins before operation	C.S.	Fresh stillborn foetus with cord twice round neck. Resuscitated by external subcostal cardiac massage. Died 26 hours later
3	Severe toxaemia, transverse lie and failed internal version. Foetal heart failed and C.S. undertaken.	C.S.	Fresh premature stillbirth weighing 2,000 g. Resuscitation failed.
4	Pre-operative intra-uterine death	F.D.	Stillborn monster
5	Pre-operative intra-uterine death (obstructed labour)	F.D.	Macerated stillborn foetus
6	Ruptured uterus in first stage of labour	C.S.	Fresh stillbirth with early postmortem changes
7	Prolapsed nonpulsating cord in second stage (twin pregnancy)	F.D.	Fresh stillbirth
8	Prolapsed nonpulsating cord on admission	F.D.	Fresh stillbirth
9	Toxaemia of pregnancy and severe accidental antepartum haemorrhage	C.S.	Fresh premature stillbirth weighing 1,500 g
10	Severe toxaemia and intra-uterine death	C.S.	Early macerated stillbirth
11	Severe toxaemia (twin pregnancy)	C.S.	Second foetus—macerated monster
12	Toxaemia and severe antepartum haemorrhage (placenta praevia)	C.S.	Stillborn monster
13	Severe eclampsia at 30 weeks previous intra-uterine death	C.S.	Macerated stillborn

*F.D.=Forceps delivery. C.S.=Caesarean section

TABLE IX

Details relating to remote neonatal deaths from patients anaesthetized with thiopentone-suxamethonium sequence

	History	Procedure*	Time of death	Cause of death
1	Delay and malpresentation	F.D.	6 hrs	Cerebral haemorrhage from tentorial tear
2	Delay and foetal distress	F.D.	4 days	Congenital abnormalities
3	Delay and foetal distress	F.D.	4 mins	Severe tentorial tear
4	Malignant hypertension	C.S.	18 hrs	Hyaline membrane
5	Prolapsed cord and transverse lie	C.S.	12 days	Berli meningitis
6	Toxaemia, foetal distress and prematurity	C.S.	3 days	Ceberal congestion and prematurity
7	Severe antepartum haemorrhage (Hb=56%); placenta praevia	C.S.	11 hrs	Hyaline membrane
8	Accidental antepartum haemorrhage and foetal distress	C.S.	4 days	Neonatal pneumonia
9	Delay with maternal and foetal distress	F.D.	5 hrs	Cyanotic attacks (patchy atelectasis at postmortem)
10	Rhesus incompatibility and foetal distress	C.S.	8 hrs	Cerebral oedema (after exchange transfusion)
11	Delay malpresentation and maternal distress	F.D.	12 days	Haemolytic disease
12	Placenta praevia, and foetal distress with prematurity	C.S.	26 hrs	Cerebral oedema and prematurity
13	Antepartum haemorrhage and transverse lie (placenta praevia)	C.S.	12 days	No satisfactory cause of death found
14	Accidental antepartum haemorrhage	C.S.	14 hrs	Atelectasis (intra-uterine asphyxia)

*F.D.=Forceps delivery. C.S.=Caesarean section

diverge as far from normal anaesthetic routine as the practice of obstetrics diverges from surgery.

For the obstetrician, already responsible for the safe conduct of labour, the additional problems are no less. In foetal distress, lack of the necessary personnel or delay in the induction of surgical anaesthesia may further jeopardize the life of the infant. Once general anaesthesia has been induced the obstetrician often feels constrained to hasten. These efforts to make good lost time, and to remove the infant expeditiously from the toxic effects of depressant anaesthetic drugs, are redoubled in the presence of foetal distress, when it is known that the infant's environment may have already become untenable. Further anxieties and frustrations may befall the obstetrician when anaesthesia becomes necessary. Attention has been drawn to the fact that difficult anaesthetic problems in obstetrics are often left in the hands of the most junior member of the anaesthetic staff, or indeed in those of any doctor irrespective of anaesthetic training. Wrigley (1955) complained, further, that whereas enormous advances have been made in the safety of anaesthetics and their administration in most other branches of medicine, "ordinary obstetric anaesthesia" had stood still.

The inherent dangers for the foetus of added hypoxia and narcotic depression associated with anaesthesia have not been so widely publicized, possibly because the effects have not always been recognized, and also because it has been believed that, unlike the anaesthetic maternal deaths, these depressant effects are unavoidable. Wendl (1955), Taylor (1956), and Henderson et al. (1957), however, avoid general anaesthesia, the first author claiming that 70 per cent of frail neonates die within 24 hours in such cases. Some anaesthetists confine themselves to the exclusion of certain specific drugs such as the relaxants (Airey, 1957) or intravenous barbiturates (Collier, 1956), on the grounds that these may adversely effect the foetus and, further, contribute to the likelihood of gastric regurgitation and asphyxia. There seems to be general agreement that agents such as ether, cyclopropane, thiopentone (when used for maintenance), and nitrous oxide in anoxic concentrations, may dangerously depress the foetal respiratory centre.

Obstetric anaesthesia entails special dangers for the mother that are well recognized. Edwards et al. (1956) reporting on deaths due to anaesthesia over a 5½-year period, showed that 5.5 per cent of those reported followed obstetric procedures. This accounted for 33 maternal deaths in which vomiting was a factor in 52 per cent. This report concerned itself only with those deaths reported to it and was not in any way comprehensive. Merrill and Hingson (1951) quoted an incidence of vomiting at the Johns Hopkins Hospital of 6.3 per cent during general anaesthesia for obstetrics, and calculated that 100 maternal deaths a year accrue from this cause in the United States alone. Parker (1956) cited aspiration vomitus and asphyxia as a direct cause of 4 per cent of maternal deaths, while Lock and Griess (1955) attributed 2.6 per cent to anaesthesia or analgesia as a whole. Walker et al. (1957) cited 3.5 per cent of maternal deaths as directly due to complications of anaesthesia, of which no less than 65 per cent were associated with vomiting. Dinnick (1957) estimated that death from aspiration of vomitus occurs once in every 3,380 obstetric anaesthetics and states that general anaesthesia cannot be advocated without considering this most serious complication. The over-all picture suggests that between 30 and 40 maternal deaths due to anaesthesia during obstetric procedures occur each year in England and Wales.

No figures are available for the nonfatal morbidity associated with vomiting and regurgitation.

Despite this, general anaesthesia for obstetrics has, at any rate until quite recently, shown little progress. In many teaching hospitals nitrous oxide-oxygen and ether is still the method of choice, while open ether and chloroform still remain popular particularly in outlying centres. The traditional type of anaesthesia based on nitrous oxide and ether is administered largely because it is considered that should the mother vomit she will usually do so during induction, and is then better able to guard her own air passages. Chloroform, in contradistinction, is still advocated because the smooth induction lessens the risk of vomiting.

Ruddell (1956), Bingham (1957), Bourne (1958), Bakhoum and Aish (1957), Watkinson (1957), Kolstad and Schye (1957), Dance and Ward (1958), and Duffield et al. (1958) have all

advocated techniques which include muscle relaxants, but there appears to be no general agreement on the drug of choice in this respect, nor on whether the induction of anaesthesia should include thiopentone, or whether supplements such as trichloroethylene or pethidine should be used in the maintenance of anaesthesia.

It is our opinion that anaesthesia for hospital obstetrics should satisfy the following criteria:

1. *Availability of experienced personnel.*

Anaesthetic cover to an obstetric unit should be complete, available at all times and at short notice. Anaesthesia should be administered only by those with experience in this type of work.

Sudden and unexpected "panic" calls to difficult obstetric patients may lead to deficiencies and to mismanagement even with experienced anaesthetists. With the inexperienced they may lead to disaster.

Some techniques may be shown to be more suitable than others, but as always the experience of the anaesthetist is the most important factor. With the advances in technique the potential dangers of inexperience increase. In this branch of anaesthesia particularly, the hasty or inexperienced mishandling of some techniques (however strongly they may be indicated on physiological or pharmacological grounds) will invariably lead to results which reflect discredit on both the technique and the administrator, although the latter invariably escapes the more lightly.

2. *Preservation of foetal oxygenation.*

The raised basal metabolic rate of pregnancy, the increased oxygen consumption associated with both labour and anxiety, the diminution in vital capacity due to a splinted diaphragm, all indicate that the oxygen supply to the mother should be unrestricted, particularly during general anaesthesia. Certainly any decrease in oxygen uptake, even for a few moments during induction, should not be tolerated by the anaesthetist. The superimposition of further hypoxia on an infant who may be already receiving a restricted blood supply due to uterine spasm, partial placental separation, or cord entanglements, may well tip the balance between success and failure.

When the lithotomy or Trendelenburg position or the insertion of abdominal packs still further decreases the vital capacity, maternal respirations should be assisted or controlled.

3. *Protection from vomiting.*

Vomiting during induction or regurgitation with aspiration in the later stages of anaesthesia are preventable incidents (Wylie, 1955) and the anaesthetic technique should guard against such events.

4. *Lack of toxicity.*

Agents such as chloroform which have their own toxicity and danger, and drugs known to cause foetal depression, should be avoided. Further, the drugs used must be predictable in action, and without harmful side effects. Drugs which are incompatible with the commonly used obstetric drugs should also be avoided.

5. *Pleasant acceptability.*

Many women at the end of a long labour will accept any type of anaesthetic induction with relish when this is obviously instituted for pain relief. When, however, anaesthesia is for the purpose of correcting some obstetric abnormality, the natural apprehension of the mother for herself and her child should not be added to by an unpleasant or extended anaesthetic induction.

AGENTS OF CHOICE IN OBSTETRIC GENERAL ANAESTHESIA

Thiopentone.

Since the work by Crawford and Kane (1956), who stated that an induction dose of thiopentone was unlikely to influence the infant adversely, it has been more widely accepted that such administration of the drug holds little danger for the foetus, and that the time between delivery and induction is not an important factor. Here we present additional clinical evidence on these points.

Our findings suggest that if thiopentone induction of anaesthesia influences the infants at all, those delivered between 4 and 10 minutes after induction are most adversely affected. In contrast to the feelings of Crawford and Kane (1956) and Steele (1957), we feel that there is something to be gained by the rapid extraction (within 4 minutes) of the infant, particularly in patients showing pre-operative foetal distress. However, speed should never take precedence over other factors possibly more important. Our clinical findings do

not in any way contradict the experimental findings of others. McKechnie and Converse (1955) showed that the thiopentone concentration in foetal serum rose for the first 3 minutes and Crawford and Kane (1956) found it to correspond with the level in the maternal serum. We are satisfied that any minimal effects of thiopentone on the infants are completely offset by the advantages derived from a smooth and rapid induction without cyanosis.

Suxamethonium.

With both d-tubocurarine chloride and gallamine triethiodide, traces of the relaxant have been shown to appear in the foetal serum (Crawford and Gardiner, 1956), the latter in appreciable quantities. Beck and Nold (1957) have shown that foetal movements in utero ceased when small doses of either of these two agents were administered to the mother. The movements returned on the administration of an anticholinesterase. For these reasons we avoid such agents. No comparable investigations have been carried out with suxamethonium, but on clinical grounds it would seem that this relaxant has no deleterious effect on the infant, an impression substantiated by others (Kolstad and Schye, 1957; Duffield et al., 1958; Dance and Ward, 1958).

We use suxamethonium as the relaxant of choice in the technique. In the early stages of the investigation an effort was made to ensure that the mother's spontaneous respiration had returned before delivery of the infant, but now with the added and gradual accumulating clinical experience gained no particular effort is made to do this. The maintenance of adequate relaxation in the induction-delivery interval has enabled us to dispense with supplemental drugs which are known to depress foetal respiration. With most patients, apnoea is maintained beyond delivery, and we have never seen a clinically "curarized" infant following such maintenance.

CONCLUSIONS

It is obvious that in our comparisons of technique the small number of patients involved and the many variable factors present prevent any statistically justifiable conclusions. It is suggestive, however, that although the incidence of foetal distress before Caesarean section was highest in the thiopentone-suxamethonium-nitrous oxide series (table VII) yet in these patients the infants were delivered in the best condition (tables VI and VII). Furthermore, the conclusion that certain agents depress the infant and are best avoided has been substantiated by others. Particularly is this true with cyclopropane (Apgar et al., 1957; Sjostedt and Rooth, 1958), with pethidine (Roberts et al., 1957), with ether (Kolstad and Schye, 1957), and trichloroethylene (Donald et al., 1958).

It is undoubtedly fair to conclude that in practice the technique which we have now adopted in this unit appears to produce the best results and to satisfy all the criteria outlined. The technique, however, demands full and adequate facilities, experienced anaesthetists, and strict attention to detail.

During the analysis and preparation of the clinical data which appears in this paper, other workers have published results of investigations that are in some respects comparable to our own. Kolstad et al. (1957), using a nitrous oxide-suxamethonium induction for Caesarean sections in 160 patients, found a greater decreased incidence of foetal asphyxia than occurred in a series of 137 patients in whom nitrous oxide-ether had been used. But with the nitrous oxide-suxamethonium induction they also found the incidence of patients showing excitation, cyanosis, mucus secretion and vomiting to be still present, although lower than in the ether series (21.1 per cent compared with 46.6 per cent). We have found that the combination of thiopentone with the rapidly acting relaxant at induction reduces the incidence of such complications to negligible figures. Duffield et al. (1958) used a thiopentone-suxamethonium induction in 338 Caesarean sections, but thereafter supplemented the anaesthetic with both ether or cyclopropane and d-tubocurarine or gallamine triethiodide. In their series the time between delivery and first cry (or regular respirations) averaged 4.5 minutes. We feel that the multiplicity of relaxants and the additional anaesthetic supplementation renders both the technique more complicated and decreases the likelihood of spontaneous respirations in the infant within 2 minutes of delivery. The mean breathing time in 264 cases of Caesarean section in our series was 1.50

minutes, a figure which compares closely with that found by Dance and Ward (1958), who reported on 63 Caesarean sections anaesthetized with a technique similar to our own.

We advocate general anaesthesia for the majority of obstetric surgical procedures. In our experience conduction anaesthesia does not fulfil the criteria previously outlined, and general anaesthesia administered by trained anaesthetists is more suited to the conditions prevailing in this country.

It is universally accepted that dangers from vomiting and regurgitation may be overcome by emptying the stomach before induction of general anaesthesia either by aspiration or by emetic drugs such as apomorphine, but we feel that neither the passage of a stomach tube nor the use of such drugs is normally indicated in the conditions prevailing in our unit. Much can be achieved in elective cases by the restriction of oral feeding and in all patients by the routine use of the head-up position during anaesthetic induction, followed by rapid oral intubation. It is our opinion that those rare patients in whom intubation is impossible, even when fully relaxed, can be detected by careful inspection of the teeth and jaw pre-operatively. In such patients emptying of the stomach before induction or the adoption of some other anaesthetic technique may be indicated. Although we do not use such procedures routinely, it is for the individual anaesthetist to decide in each case whether or not a stomach tube should be passed, and adequate suction apparatus must be available at all times (see plate I). On occasions the stomach is aspirated during the latter stages of the anaesthesia, for vomiting during the recovery period can be no less dangerous. Routinely our patients are not extubated until the reflexes return postoperatively and the patient is turned on her side. The incidence of vomiting during induction in our series has been nil, and the incidence of regurgitation during laryngoscopy for intubation restricted to two early cases who were anaesthetized in the horizontal position.

The ready availability of trained personnel interested in this specialty has reduced to a minimum some of the hazards and the delays which have been in the past associated with obstetric anaesthesia. However, when considering the choice of obstetric anaesthesia in the light of present-day knowledge of pharmacology and foetal physiology, it must be conceded that this greater knowledge and the use of more complex techniques can only lead to greater safety when handled by knowledgeable and trained anaesthetists. The most important single factor still remains the man and not the method. Nevertheless there appears to be no doubt that when other factors are eliminated a properly chosen anaesthetic technique can well tip the balance between tragedy and success.

SUMMARY

The effect on the infant of various general anaesthetic techniques has been compared in 264 deliveries.

The criteria for obstetric anaesthesia are outlined, and the particular problems discussed.

A technique using thiopentone, suxamethonium, nitrous oxide and oxygen is described, and the reasons are given for considering this technique superior to others. The results of its use in 600 patients (Caesarean sections and forceps deliveries) are presented.

The availability of anaesthetists specially trained and interested in obstetric anaesthesia is important for the success of the method described.

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THE INDUCTION OF ANAESTHESIA: A SAFE TECHNIQUE FOR THE NOVICE

BY

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PROGRESS in anaesthesia has been such that, in the British Isles, most anaesthetics today are administered by specialist anaesthetists. However, a certain proportion of patients will continue to be anaesthetized by those who are undergoing training and by newly qualified practitioners. The hazards of anaesthesia are quickly brought to the attention of the trainee anaesthetist, who is fortunate in that supervision is usually adequate to compensate for possible errors in his technique and defects in his judgment.

In many hospitals, the pressure of work on a small anaesthetic staff renders such supervision imperfect. Thus a newly qualified practitioner may be required to anaesthetize the cases at the end of the surgical list or to give a "quick anaesthetic" for a forceps delivery. Edwards, Morton, Pask and Wylie (1956) have drawn attention to the tendency for obstetric anaesthetics to be relegated to junior and inexperienced staff.

Where anaesthesia is conducted by relatively untrained personnel, it is important that the methods and agents should be as uncomplicated and safe as possible. The purpose of this paper is to describe a technique for the induction of anaesthesia which we believe is easy to learn and safe to perform. No claim is made that this technique is original, although to our knowledge it has not previously been described.

TECHNIQUE

The standard Boyle's anaesthetic machine is carefully checked and the oxygen and nitrous oxide flowmeters are opened so that flow rates of 2 l./min of oxygen and 6 l./min of nitrous oxide are delivered. The ether tap is opened until it stands in the vertical position, so that the gases pass into the ether bottle, which is filled to the 8-oz. level. The plunger is depressed until it lies just above the surface of the ether. Delivery of these agents to the face piece is effected by way of the standard Magill attachment, or in children through a T-piece circuit.

The mask is now held at a distance of approximately 12 inches from the patient's face and lowered very gradually and steadily over a period of 4–5 minutes, by which time it is in contact with the face and the patient is asleep. The jaw is now supported and anaesthesia is maintained with the same concentration of nitrous oxide and ether.

RESULTS

This technique has now been employed in a considerable number of cases with good results. Many children have been anaesthetized by students who have had no previous instruction in other methods of anaesthesia. In no instance has there been any cyanosis, laryngeal spasm or vomiting during induction. The method has also been employed in obstetrical anaesthesia, where even in the hands of the inexperienced it provides a smooth and uneventful induction. Where the anaesthesia was maintained with the nitrous oxide, oxygen and ether mixture unchanged, vomiting during recovery has been remarkably rare in cases of short duration.

DISCUSSION

Di-ethyl ether is reputed to be one of the safest agents in common use. Accordingly, it is the agent most frequently chosen when the anaesthetist is inexperienced. It may be administered alone by the open mask technique, or following induction with ethyl chloride or nitrous oxide and oxygen. The marked irritant action which this agent exerts on the respiratory passages is a disadvantage which calls for careful judgment in the in-

crease of vapour concentration if spasm, coughing and hypoxia are to be avoided. When it is used in conjunction with the open mask technique, hypoxia cannot be avoided unless oxygen is introduced under the mask. The rate at which ether may be dropped on the mask is something which may only be learnt after some experience. Thus the administration of open ether is an art which is acquired only after a certain number of patients have been exposed to the hazards of laryngeal spasm, vomiting, coughing and hypoxia. The novice may well find that some considerable dexterity is required if he is to support simultaneously the jaw, the mask, the oxygen lead and the drop bottle.

Ethyl chloride is possibly the most toxic anaesthetic agent still in common use. Edwards, Morton, Pask and Wylie (1956) have drawn attention to five deaths which occurred in healthy children following the use of the ethyl chloride, open ether sequence for minor operations. Overdosage with this agent can occur so readily that it is feared even by anaesthetists with considerable experience. When used in conjunction with the open mask technique, the tension of anaesthetic agent under the mask may lead to a severe degree of hypoxia. It is difficult to understand why such an agent is still tolerated and unthinkable that it should be placed in the hands of a novice.

In the standard method of induction with the nitrous oxide, oxygen and ether sequence, the patient is rendered unconscious with a concentration of nitrous oxide that entails a varying degree of hypoxia. The ether tap is then opened gradually, and as the vapour becomes effective so is the oxygen concentration increased. If the ether concentration is increased too rapidly, laryngeal spasm results in a patient who is already hypoxic.

While this method of induction may be safe when performed by an expert, it cannot be considered to be an ideal procedure for the novice.

Thus a safe method of induction must provide facilities for a smooth and gradual increase in ether concentration and an anaesthetic atmosphere which contains an adequate percentage of oxygen at all times. The method described lessens the risk of sudden changes in the concentration of ether vapour as all that is required in order to provide a smooth and steady increase is that the hand supporting the face piece be moved slowly and steadily towards the face. Difficulties which may arise owing to the presence of a high initial concentration of vapour in the ether bottle and variations in the action of ether taps on the anaesthetic apparatus are thus eliminated.

Laryngeal spasm, vomiting and coughing are unlikely and the oxygen concentration of the inspired mixture is never below 20 per cent during induction. Where the face mask descends slowly and the jaw is properly supported following induction, the possibility of hypoxia becomes remote.

Anaesthesia may be maintained with the same relative concentrations of nitrous oxide, oxygen and ether. As experience is gained the technique may be varied as required to encompass anaesthesia for more major procedures.

While we would emphasize that this method is described mainly to assist the student and novice, there may be occasions when more experienced anaesthetists would find it useful. Thus we have employed the technique occasionally when presented with children who were uncooperative or asleep and in certain cases in poor general condition, such as severe burns with inaccessible veins. The speed of induction, by modern standards, is slow; and in infants the deadspace present in the mask must contra-indicate the maintenance of anaesthesia by such a technique for any but the shortest of procedures, although carbon dioxide accumulation may be minimized by the use of high flow rates. The patient may complain of the irritant action of ether vapour on the conjunctiva. This appears to be minimal, however, and is easily remedied if the eyes are closed during induction. Most children tolerate the mixture without complaint if encouraged during induction, especially during the initial period, and it appears to be readily accepted by obstetrical cases. These disadvantages may appear to be of little consequence in return for safety and simplicity.

SUMMARY

A certain proportion of anaesthetics will continue to be administered by students and medical practitioners with little experience in the specialty. It is suggested that under such circumstances cer-

tain disadvantages exist when the standard techniques of induction with nitrous oxide, oxygen and ether or ethyl chloride and ether are employed. A simple technique is described which enables induction to be performed by the novice with a minimum of risk. This technique has also been used with success in a number of cases which were considered to be poor anaesthetic risks. It may be of value in the instruction of students, especially in that it can be mastered in the short time provided for the teaching of anaesthesia in most medical curricula and in that it can be varied to encompass anaesthesia for more major procedures as experience is gained.

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FACULTY OF ANAESTHETISTS
OF THE
ROYAL COLLEGE OF SURGEONS OF ENGLAND

BURROUGHS WELLCOME FELLOWSHIPS

The Burroughs Wellcome Fund in the U.S.A. has founded a Fellowship in Anaesthesia at the University of California Medical Center, Los Angeles, to give a British physician in training in anaesthetics the opportunity of the cultural, academic and professional experience of an American university and to increase the understanding of anaesthetics between the physicians of the United States and Great Britain. The value of the Fellowship is 4,000 dollars p.a., including travelling expenses. This amount has been found by the existing Fellow to be adequate to cover normal requirements. The Fellowship has been founded for three years to support three Fellows for one year each, and the Fellows are expected to return to Britain upon the completion of the terms of their respective Fellowships. The Fellowship is for both clinical and research work.

Anaesthetists who have passed at least the Primary Examination for the F.F.A.R.C.S. are invited to apply for the second annual award. The Fellow appointed will be expected to take up his duties as soon as possible after September 1, 1959. Applications, giving details of qualifications and experience (including research experience, if any) and the names of two persons to whom reference may be made if necessary, should be sent to R. S. Johnson-Gilbert, Esq., M.A., Secretary, Faculty of Anaesthetists, Royal College of Surgeons of England, Lincoln's Inn Fields, London, W.C.2, not later than Thursday, July 16, 1959.

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ACUTE HYPERTENSION DEVELOPING UNDER ANAESTHESIA: A NEAR FATALITY

BY

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CASE REPORT

A male patient, D.C., aged 30 years, a plumber, was seen in the Neurological Department complaining of pain in the back, numbness in the feet, and difficulty with walking.

Eight months previously he had twisted his back swinging a sledgehammer, and had subsequently had pain in his left hip and knee. Four months later he had felt "something give way" in his back in the lower thoracic region, and it had remained sore. After that there was a gradual onset of numbness and weakness, which started in the feet and slowly travelled upwards, eventually resulting in difficulty in walking. Bowel function and micturition remained normal. There was nothing relevant in either the past history or the family history.

On examination he appeared a healthy young man. Neurologically a level was found, at T6 on the right and T7 on the left, below which all forms of sensation were diminished. In the feet sensation was almost absent. In the reflexes the lower abdominals were absent, the knee and ankle jerks were increased bilaterally, and the plantar responses were extensor. There was no real tenderness over the spine. In the cardiovascular system nothing abnormal was found, but the blood pressure was 160/100 mm Hg. The respiratory and other systems were all clinically normal.

In the special investigations, lumbar puncture showed a complete subarachnoid block. A radiograph of the chest was normal, but a picture of the dorsal spine showed erosion of the left pedical of T10. Myelography confirmed erosion of this pedicle, and revealed a block at T10-11 to ascending myodil; the appearances suggested a left-sided space-occupying lesion. The diagnosis made was spinal cord compression by ? neurofibroma.

The patient came to theatre for dorsal laminectomy. Premedication was with papaveretum 20 mg and hyoscine 0.4 mg subcutaneously. The blood pressure, taken immediately before induction of anaesthesia, was 160/100 mm Hg. Induction was perfectly smooth, and was effected as follows: thiopentone sodium 5 per cent solution was given intravenously slowly to about twice the "sleep dose", followed by suxamethonium chloride 70 mg; after inflation of the lungs with oxygen the larynx and trachea were carefully sprayed with cinchocaine 2 per cent solution using 2 ml; a No. 11 flexometallic endotracheal tube was passed and stabilised by means of two throat packs and adhesive strapping; the lungs were inflated rhythmically with $N_2O:O_2$ mixture (6:2 litres) until spontaneous respiration returned in a few minutes; a low concentration of trichloroethylene vapour was added at this point. The patient's breathing was entirely free and natural. An intravenous drip was then set up in the ankle. This occupied only a few minutes, but on palpating the pulse again it was found to be irregular, exhibiting numerous ectopic beats. The trichloroethylene was turned off, but we were surprised that such a low concentration of vapour should have produced pulse irregularities so quickly. Within a minute or two the irregularity had disappeared. The patient was now rolled gently off the trolley on to his face on the operating table, so that his body was padded by pillows under the chest, pelvis, and feet. The table was tilted slightly foot-down, and was wheeled into the theatre.

The operation site was prepared and infiltrated with 0.5 per cent procaine solution, and then towelled up. As soon as the skin was incised blood flowed freely, and the surgeon commented on this. At this point the pulse was found to be grossly irregular and very rapid, and the blood pressure was 280+/130 mm Hg. This dramatically confirmed our suspicions that there was something peculiar about the patient, for there was nothing in the course of the anaesthesia or handling of the patient that could account for even the slightest hypertension, let alone the gross pulse irregularity and tachycardia. An immediate check was made in case adrenaline might accidentally have been injected, either when infiltrating or earlier. Procaine amide intravenously, 300 mg, over 3 minutes, restored regular rhythm at a rate of 180/minute. Trimetaphan, which had been set up previously ready for infusion, was run in fairly rapidly, *but had no effect whatsoever*. Bleeding from the operation wound after the muscles had been stripped off the vertebrae was very severe and difficult to control. At this point the diagnosis of a phaeochromocytoma was made by the authors.

The surgeon was highly sceptical because of the lack of any previous history to suggest this condition, but in view of all the circumstances the authors urged that the operation should be stopped since continuation seemed not only technically very difficult but even foolhardy, and the surgeon acquiesced.

After the patient had been rolled back into his bed his blood pressure was 180/110 mm Hg pulse 175/minute, axillary temperature 100.8°F and rectal temperature 102.4°F. Fifteen minutes later he was conscious, pallid, sweating and had some headache. He looked extremely ill. Over the next few hours his blood pressure and pulse settled and he gradually recovered to normal. All urine voided was kept for examination.

Further questioning of this patient revealed some interesting points which had not come out previously.

He had suffered from attacks of sweating at night, up to three times in a week, which were severe enough to cause him to get up and dry himself with a towel; headache was sometimes present also. The attacks never occurred in the day time. He had had headaches during the day, however, and these were sometimes accompanied by palpitations. Two years previously, when he was in the army, he complained of sweating attacks and was subsequently investigated for "hypertension and albuminuria", but nothing abnormal was found.

Examination of the 24-hour specimen of urine for catechol amines revealed 4,500 μg/24 hours, which is equivalent to 150 mg of noradrenaline, and is about thirty times the normal maximal value. This established the diagnosis. Careful clinical examination now disclosed a palpable mass under the left costal margin (kidney), and the liver edge two finger-breadths below the right costal margin.

Special investigations were as follows:

i.v. pyleography: left kidney pushed downwards.

Glucose tolerance: diabetic type of curve.

Blood urea, urinary 17-ketosteroids and 17 ketogenic steroids and e.c.g. were normal.

Radiography: areas of bone destruction visible in left ischium and ilium.

These findings localized the tumour to the left side, and suggested that it was malignant with secondary deposits in the hip and spinal column which accounted for his symptoms.

He was treated with phentolamine 100 mg t.d.s., and a course of deep radiotherapy was given over five weeks which seemed to be completely successful. On discharge (seven weeks after the attempted operation) the patient was able to walk, although his legs were still weak; the tendon jerks were still augmented, but the plantar responses were flexor. No sensory disturbance at all remained. At follow-up a fortnight later he was continuing to progress satisfactorily.

The diagnosis of phaeochromocytoma is certain. Whether it is malignant is not proved, but the presence of what appear to be bone deposits and the prompt response to deep radiotherapy suggest that it is.

DISCUSSION

There have been several excellent reviews and many case reports of phaeochromocytomata to which the reader may refer (Millar, 1957; Graham, 1951; Wordsworth, 1955). The immediate problem for the anaesthetist is to decide what he should do when faced with the circumstances described. Paroxysmal hypertension under anaesthesia is now a well recognized mode of presentation of phaeochromocytoma, and the gravity of the situation will be apparent from a consideration of some of the salient facts about these tumours.

Although the condition is rare, accounting for only about 0.5 per cent of cases of hypertension in Smithwick's series of sympathectomies (Smithwick et al., 1950), it is estimated to account for 600–800 patients annually in the U.S.A. alone (Graham, 1951). This would give a proportionate figure for Great Britain of about 200 patients per annum. If 2,000,000 general anaesthetics are administered each year (probably an underestimate) among a population of 50,000,000 then one might expect no less than eight cases of phaeochromocytoma among these 2,000,000 people. And any or all of these eight might well die as a result of their anaesthesia.

It is extremely dangerous. Of all cases 70 per cent are diagnosed only postmortem. Death occurs either during a hypertensive crisis or soon after. In the first case it is due either to cerebral haemorrhage (systemic hypertension), pulmonary oedema (pulmonary hypertension), ventricular fibrillation (adrenaline $\pm$ cardiac hypoxia), or acute ventricular failure (systemic hypertension $\pm$ adrenaline intoxication). In the latter case it is due to the severe reactionary hypotension, which may in turn be due to the cessation of the massive outflow of noradrenaline from the tumour (cf. noradrenaline drips), or to its continuation (Freeman et al., 1941; Blacket et al., 1950), or to continuing left ventricular insufficiency (Bartels and Cattell, 1950), and on which occasionally a chronic adrenal cortical dysfunction may be superimposed (Richards and Hatch, 1951; Neff et al., 1942).

It is completely curable in most cases. Roughly 90 per cent of cases are benign, 90 per cent are unilateral, and 90 per cent are in, or near, the suprarenals (Thompson and Arrowood, 1954).

Operation is hazardous. Graham (1951) quotes a mortality of 26 per cent of 126 cases, and Morris (1954) quotes 20 per cent of 106 cases. The causes of death are those listed above. Out of 32 recorded deaths, quoted by Graham, two-thirds occurred at operation or within 8 hours postoperatively; 19 were due to hypotension after the tumour had been removed, 3 were due to pulmonary oedema, 2 to haemorrhage, 1 to cardiac failure, and 3 to hyperpyrexia. Death may occur during anaesthesia, before operation, presumably from adrenaline intoxication. Induction of anaesthesia often produces hypertension. Intubation, among other factors, may cause cardiac arrhythmias. Positioning the patient may precipitate an attack; lying down may in itself cause some hypertension in these patients, but pressure on the abdomen is extremely likely to

initiate a crisis. Manipulation of the tumour nearly always produces severe hypertension, and after it is removed there is severe reactionary hypotension.

Adrenolytic drugs are an effective safeguard since all the symptoms and signs are directly due to an excess of circulating catechol amines. Ganglionic blocking agents, such as trimetaphan, should not produce any significant fall of blood pressure during a hypertensive crisis for the same reason; in fact, by blocking the motor side of the autonomic reflexes which buffer changes of blood pressure (carotid and aortic reflexes) these drugs may increase the effect of circulating adrenaline in animals (Moe, 1948) and man (Page and Taylor, 1947, 1950). Phentolamine is generally recommended as combining effectiveness against the dangerous effects of adrenaline with freedom from side effects. Noradrenaline is effective in maintaining the blood pressure postoperatively: in the rare cases of adrenocortical insufficiency hydrocortisone would be needed also.

The case reported here exhibits a number of interesting points.

Arrhythmia was first noted about 5 minutes after the start of anaesthesia; it may have been due to the small dose of trichloroethylene being administered, which would lend some support to the popular fear of adrenaline infiltration in the presence of this drug, but it may equally well have resulted from the stimulus of intubation under light anaesthesia (in the presence of circulating adrenaline), or even solely upon the release of adrenaline consequent upon the induction of anaesthesia. The arrhythmia disappeared within a minute or two of turning off the trichloroethylene, but it was observed again, in combination with gross tachycardia, at the beginning of the operation; this time it responded to procaine amide, but the tachycardia remained. One might expect that since phaeochromocytomata contain mainly noradrenaline, bradycardia would be a feature of the attacks; however, tachycardia is always reported, and Hamilton et al. (1953) have shown that sufficiently large doses of noradrenaline do in fact cause tachycardia.

Concerning the effect of positioning this patient, it may be significant that he never had sweating attacks in the daytime (though he did sometimes have headaches) but only at night; his tumour may have been particularly sensitive to posture and pressure, and in that event attempted dorsal laminectomy must have been a potent stimulus to liberation of catechol amines.

The original diagnosis was intraspinal neurofibroma. Since the events reported this spinal tumour has been assumed to be a secondary deposit, and since the neurological symptoms have receded so much after deep radiotherapy the assumption seems justified. However the incidence of neurofibromata together with phaeochromocytomata is estimated as 10 per cent at least (Glushien et al., 1953; Rosenthal et al., 1936), and in such cases the chromaffin tumour is always in, or near, the left adrenal—as in this case.

The complete absence of response to ganglionic blockade was striking, but is exactly what one would expect. It virtually proved the diagnosis in itself.

CONCLUSIONS

These fundamental facts lead the writers to suggest the following line of treatment when a previously unsuspected phaeochromocytoma is unmasked on the operating table.

First, the operation must be stopped. The mortality rate even among prepared patients is very high, and is twice as high in the unprepared (Apgar and Papper, 1951). In addition, operative bleeding may be so severe as to make surgery almost impossible.

Secondly, a short acting ganglionic blocking agent should be administered; absence of response of the blood pressure is evidence of a circulating hypertensive agent. This valuable diagnostic step can be criticized as likely to increase the already dangerous hypertension in phaeochromocytoma cases; we feel, however, that under anaesthesia the buffer reflexes are likely to be at least partially obtunded in any case and provided a short acting drug, such as trimetaphan or homatropinium is used there will be no adverse effects.

Thirdly, if the ganglionic blocker produces no relief of the hypertension phentolamine should be given. A marked fall of blood pressure in response to 5 mg given intravenously is indicative of the presence of circulating adrenaline and/or noradrenaline. The phentolamine should then be continued as an intravenous drip to retain control of

the blood pressure (Terry et al., 1958). Noradrenaline may be needed subsequently.

SUMMARY

A case of phaeochromocytoma is described which was diagnosed during anaesthesia on account of the classical picture presented, and subsequently confirmed. There is evidence that such an event is likely to be commoner than one might at first sight imagine. Consideration of the main features of the condition reveals the vital importance of correct immediate treatment, and a line of action is suggested.

ADDENDUM

This patient underwent laparotomy on January 13, 1959, and a left suprarenal tumour was removed; it was about the size of a fist and appeared, macroscopically and histologically, to be a malignant phaeochromocytoma. In spite of pre-operative medication with phentolamine, induction of anaesthesia caused a small transient hypertension (120/70 mm Hg → 140/80 mm Hg) and a marked tachycardia (65/min → 120/min) giving way, after turning the patient into the right lateral position, to a fall of blood pressure to 95/40 mm Hg and pulse rate of 48/min.

As the operation proceeded the blood pressure rose steadily and the pulse became increasingly more irregular. The e.c.g. (lead I) showed first normal rhythm at 48/min → ventricular ectopic beats → atrio-ventricular dissociation → increasing numbers of ectopic beats culminating in multifocal ventricular tachycardia at 170/min, at which point phentolamine was administered intravenously rapidly. Within 3 minutes, 2 mg of phentolamine having been given, the e.c.g. had reverted to normal rhythm (although the T waves remained large and peaked), and the blood pressure had fallen considerably.

Twenty-five minutes later, 5 minutes after the tumour was removed, the blood pressure fell precipitately. A noradrenaline infusion stabilized it at around 100 mm Hg; it was discontinued finally 9 hours later. Convalescence was uneventful.

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FURTHER TRIALS OF LIGNOCAINE IN SPINAL ANAESTHESIA

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SOME explanation should be made for the presentation of a paper on subarachnoid spinal anaesthesia at a time when most anaesthetists in Great Britain have abandoned the technique. There are vast areas in the British Commonwealth and in other parts of Asia and Africa where thousands of spinal anaesthetics are administered every year. The main reasons for this are undoubtedly the shortage of anaesthetic equipment, the prohibitive cost of cylinder gases and the scarcity of anaesthetists. This situation will persist for many years to come, and one cogent reason is the fact that rudimentary practice with a minimum of equipment will continue to be the first surgical service to reach that large proportion of the earth's population in the undeveloped areas suffering from hitherto untreated gross pathology. The fact that surgeons working in hot climates believe that their patients fare better after spinal anaesthesia than after general anaesthesia cannot be supported by any statistical evidence, because it is in those very regions that adequate records are generally not obtainable. Nevertheless this clinical impression is also responsible for the continued wide use of spinal anaesthesia. Having regard to these facts it was thought expedient to investigate the action of lignocaine hydrochloride to see if it has any obvious advantages over the drugs used at the present time.

In a previous publication on the subject of intrathecal lignocaine, Adams (1956) preferred a 5 per cent solution with 3.1 per cent glucose because of the absence of caramelization on autoclaving. She found the onset of anaesthesia to occur within 3 to 10 minutes; motor paresis was complete in 80 per cent of the cases, and the duration of anaesthesia was 2 hours. This duration of about 2 hours was confirmed by Walker (1957), who found that the same preparation in a dose of 75 mg gave a wider block and greater paresis than 7.5 mg of cinchocaine. Featherstone (1958) gave the duration of lignocaine spinal anaesthesia as between $2\frac{1}{2}$ and 3 hours.

Presented here are the results derived from five solutions of lignocaine hydrochloride which have been compared with standard solutions of procaine, amylocaine, amethocaine and cinchocaine, all the cases being subjected to the same method of analysis.

TECHNIQUE

Following intravenous premedication a preliminary subcutaneous injection of ephedrine 40 mg in 1 per cent procaine was made over the selected interspace. The ampoules of spinal drugs were not autoclaved before use but were taken from the cardboard packages supplied by the manufacturers and examined for cracks, loss of fluid volume, deposits and discoloration. The ampoules were then wiped clean of dust with dry gauze and opened by an assistant. If the ampoule was suspect or there was any failure to obtain a clean break in the glass, it was rejected. In each case either 21 or 22 s.w.g. Luer Lok short bevel needles were employed. The apparatus and towels were autoclaved before use.

In the results shown in tables I, II and V, the data were obtained as follows. "Onset" referred to the time from injection to that when nearly full sensory and motor block was obtained. A slow subsequent spread, particularly with lignocaine, was ignored for this purpose. "Recession" indicated the time from full onset to that when a definite complaint of pain from previously insensitive tissues occurred during surgery, or when an obvious return of motor power was noticed. Unless arising near the time of completion of wound closure, recession necessitated the administration of supplementary general

TABLE I
Results from lignocaine

Solution	Cases	Mean dose and range (ml)	Mean time of onset and range (minutes)	Cases of recession and mean (minutes) s=sensory m=motor	Long cases (minutes)	Cases of B.P. fall		Motor block	
5% lignocaine 3.1% glucose	Total 111 Upper abdomen 19 Liver 3 Stomach 3 Gall bladder 5 Lower abdomen 73 Prostate 7 Uterus 4 Caesarean 8	1.7 (83 mg) 0.6–3.0	7.0 4–16	s. 40 48 50 50 50 55 60 60 65 65 70 70 70 75 78 78 80 80 80 80 80 80 85 100 110 m. 53 65 Mean 69	70 70 72 75 75 75 80 83 90 90 110 115	Very severe — Severe 10 Moderate 18 Slight 32		Good 84 Moderate 25 Slight 2	
5% lignocaine 3.1% glucose 0.5 ml adrenaline 1/1000 added	Total 44 Upper abdomen 5 Stomach 1 Gall bladder 1 Lower abdomen 36 Prostate 4 Uterus 5 Caesarean 4	1.7 (83 mg) 1.0–3.0	7.0 5–15	s. 30 40 50 60 75 78 80 90 90 90 95 m. 45 Mean 69	70 75 75 80 90	Very severe — Severe 4 Moderate 7 Slight 12		Good 29 Moderate 11 Slight 4	
1/200 lignocaine 0.45% sodium chloride	Total 50 Upper abdomen 17 Stomach 3 Liver 2 Gall bladder 5 Lower abdomen 27 Prostate 1 Uterus 1	14.7 (74 mg) 5.0–20.0	7.2 4–15	s. 30 30 32 34 38 45 45 45 45 45 49 50 52 55 55 65 65 70 70 75 77 80 80 85 m. 37 50 55 Mean 54	58 60	Very severe 1 Severe 4 Moderate 10 Slight 9		Good 23 Moderate 24 Slight 3	
1/210 lignocaine 0.43% sodium chloride 1/21,000 adrenaline	Total 50 Upper abdomen 27 Stomach 6 Liver 3 Gall bladder 6 Spleen 3 Lower abdomen 16 Caesarean 1	16.6 (79 mg) 10.0–21.0	7.0 1–15	s. 35 45 45 45 50 50 50 53 60 70 70 70 75 85 90 90 95 110 m. 50 65 65 Mean 65	66 67 70 70	Very severe 1 Severe 5 Moderate 12 Slight 14		Good 34 Moderate 13 Slight 3	
1% lignocaine 0.3% sodium chloride	Total 50 Upper abdomen 17 Stomach 4 Liver 4 Gall bladder 2 Lower abdomen 24 Prostate 3 Uterus 1 Caesarean 2	13.7 (137 mg)	8.2 8–25	s. 30 45 50 50 53 55 58 60 65 65 65 65 65 65 65 67 79 85 m. 42 47 50 55 60 Mean 58	60 60 68 68 75	Very severe — Severe 6 Moderate 7 Slight 21		Good 35 Moderate 13 Slight 2	

TABLE II
Lignocaine compared with controls

Solution	Cases	Mean dose (mg)	Mean onset (mins)	Mean recession (mins)	Probable duration (mins)	Proportion of "good" motor block
5% lignocaine ... ... 3.1% glucose	111	83	7.0	69	80	76%
5% lignocaine ... ... 3.1% glucose 0.5 ml adrenaline 1/1000 added	44	83	7.0	69	80	66%
1/200 lignocaine ... ... 0.45% sodium chloride	50	74	7.2	54	60	46%
1/210 lignocaine ... ... 0.43% sodium chloride 1/21,000 adrenaline	50	79	7.0	65	70	68%
1% lignocaine ... ... 0.3% sodium chloride	50	137	8.2	58	62	70%
5% procaine in ... ... cerebrospinal fluid	35	111	5.7	61	70	77%
4% procaine with ... ... 1/5000 adrenaline in cerebrospinal fluid	36	118	6.8	58	70	47%
5% amylocaine ... ... 5% glucose	96	55	6.2	46	50	78%
5% amylocaine ... ... 5% glucose 0.5 ml adrenaline 1/1000 added	101	50	7.2	57	75	80%
1% amethocaine ... ... 5% glucose	52	13	7.4	89	100	63%
1% amethocaine ... ... 5% glucose 0.5 ml adrenaline 1/1000 added	51	15	8.0	96	110	76%
1/1000 amethocaine	68	12	8.0	75	95	90%
1/1000 amethocaine ... ... 1/20,000 adrenaline	75	13	8.0	130	150	90%
0.5% cinchocaine ... ... 6% glucose	65	8	8.6	115	125	92%
0.5% cinchocaine ... ... 6% glucose 0.5 ml adrenaline 1/1000 added	78	6	10.6	180	190	81%
1/1500 cinchocaine ... ... 0.45% sodium chloride	90	8	10.0	88	110	89%
1/1575 cinchocaine ... ... 0.43% sodium chloride 1/21,000 adrenaline	55	8	10.0	154	180	93%

anaesthesia. Under "long cases" were listed the times at which painless skin closure was executed, when they were greater than the mean recession time. Falls of blood pressure have been classified in four groups; first, "very severe", signifying a pulseless patient requiring resuscitative measures; second, "severe", meaning that there was some cause for alarm—for example, a fall to 60 mm Hg systolic from normal; third, "moderate": placed in this group were (*a*) a significant fall, but one not causing anxiety, and (*b*) a severe fall which recovered spontaneously in 5 to 15 minutes or which was due to other factors, such as posture, haemorrhage, visceral pain and the administration of supplements; and lastly, "slight" which signified a fall of some 20 to 30 mm Hg. Motor block was described as "good" when muscular relaxation was entirely satisfactory for surgery, even if a slight tone was demonstrable prior to operation. "Moderate" relaxation described barely satisfactory operating conditions although abdominal closure could be performed. "Slight" motor block indicated some relaxation but inadequate for surgical purposes.

Our experience of 15,000 spinal anaesthetics administered in this hospital over a period of nine years has led us to reduce the dosage as much as possible to avoid serious hypotension in the average, undernourished and anaemic patient. Therefore, extreme tilting was always used to obtain maximal movement of minimal quantities of solutions for upper abdominal surgery. For this reason, the doses used are smaller than is customary (table II).

INSTABILITY OF LIGNOCAINE SOLUTIONS

Unfortunately, deterioration in the potency of the 5 per cent lignocaine solution appears to have occurred from storage. Although the ampoules were not autoclaved prior to use, a progressive weakening of the response to a given dose occurred during a period of eight months. The ampoules were imported during the summer and initially stored at a temperature of 32°C; the mean storage temperature was 24°C. Three ml of solution used for the last few cases were equivalent to 2 ml employed at the beginning of the series. There was a faint yellowish discoloration and the onset of anaesthesia was slower. With fresh ampoules there was rapid onset of partial paresis in a period lasting from 30 seconds to 3 minutes following injection, whereas in the final cases both sensory and motor block appeared within 4 to 15 minutes. The figures given in table I therefore represent an average response during this period of presumed partial deterioration.

The 1 per cent lignocaine solution was not obtained from ampoules for spinal use, like the other preparations, and was made from 2 per cent "Xylocaine Plain" supplied in sterile metal and rubber-capped bottles. For the first twenty cases the bottles were autoclaved before use, but the appearance of a proportion of incomplete blocks and anaesthetic failures indicated a loss of strength due to sterilization, since the numbers were far greater than could be explained by technical errors in administration. Five case records were rejected and the remaining thirty-five cases of the series (table I) were conducted without previous autoclaving of the lignocaine. Owing to a clinical impression that there was a decrease of potency due to storage for three years at room temperature, samples were submitted for analysis. The method of chemical essay of the British Pharmacopoeia for lignocaine gave a result of 2.1 per cent which complied with the Addendum 1955 to the British Pharmacopoeia 1953. Chemically there was no evidence of deterioration.

FINDINGS

Details of the operations, the dose, the onset and duration of anaesthesia, the blood pressure fall and the motor blockade are given in table I for lignocaine solutions, and similar data for lignocaine and the other drugs are summarized in table II. The mean figures for the onset and duration for all the solutions of each drug appear in table V. In the lignocaine series there were no deaths attributable to anaesthesia and no neurological complication followed in any of the 1,107 cases in this report. Because of the ignorance and suggestibility of the majority of the patients, observation of the incidence of postoperative headache would have been valueless.

5 *per cent lignocaine.*

Figures 1 and 2 respectively are graphic representations of the development and recession of anaesthesia in a typical case and in one receiving the high dosage. The rapid onset of motor weakness, within a minute of injection, found by other

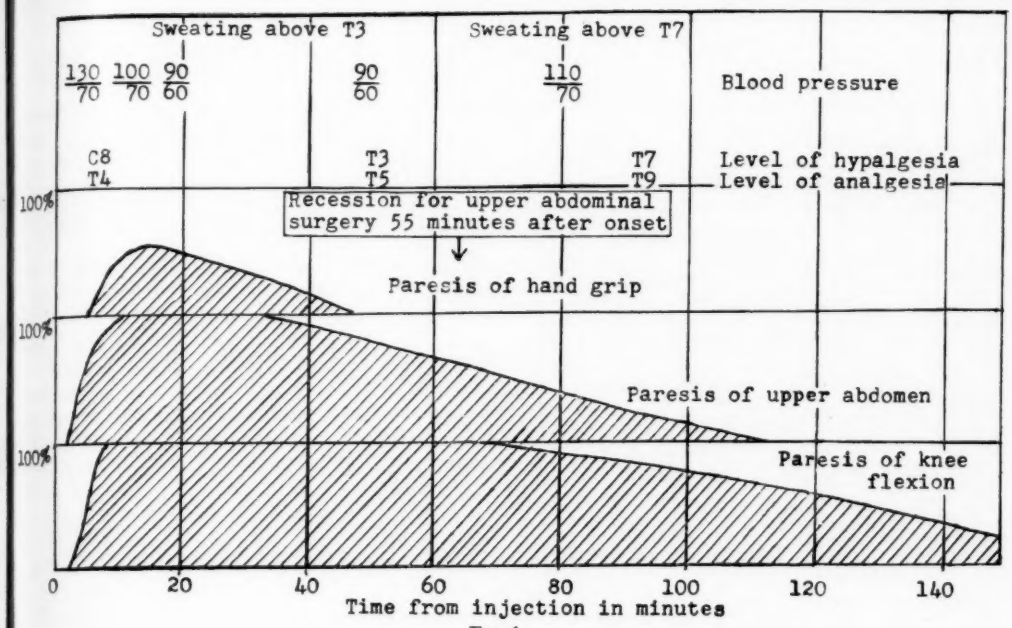

FIG. 1

A typical case of 5 per cent lignocaine.
Man aged 45 with 24 hours intestinal obstruction. Operation: reduction of viable internal hernia due to band from Meckel's diverticulum. 2 ml 5 per cent lignocaine in lateral then steep Trendelenburg position for 5 minutes.

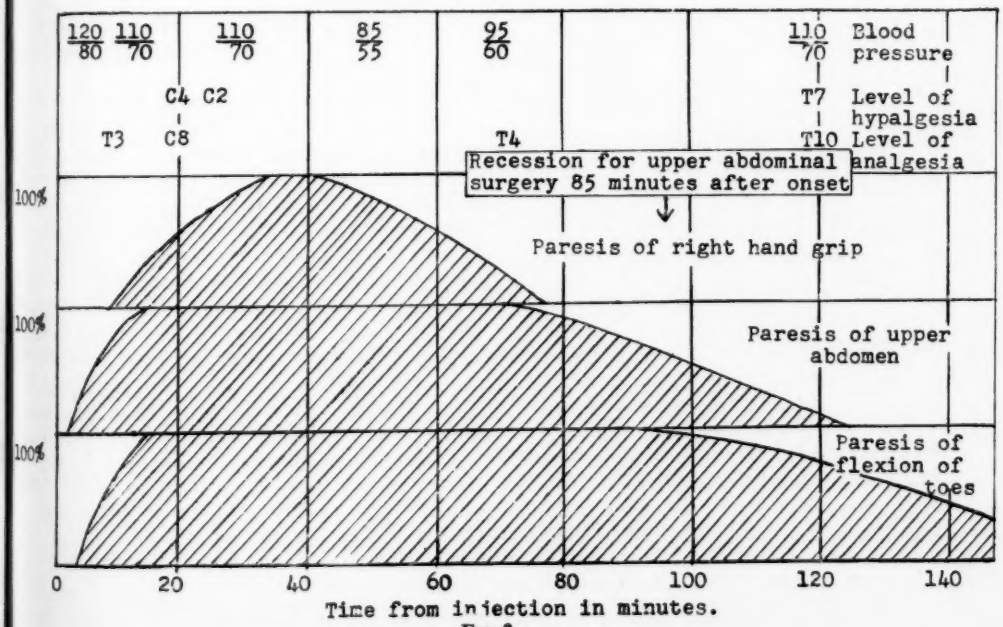

FIG. 2

One of the longest anaesthesias with 5 per cent lignocaine.
Thin tall woman, aged 47, Hb 70 per cent, not jaundiced. Operation: formalin injection and evacuation of two large hydatid cysts of liver. 3 ml 5 per cent lignocaine given in right lateral steep head-down tilt which was maintained for 5 minutes.

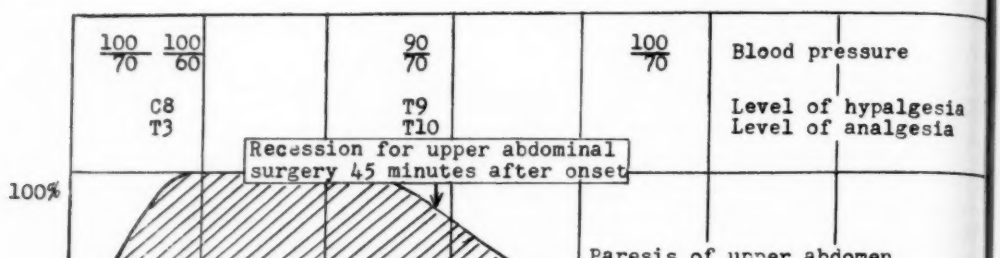

FIG. 3

A typical case of 0.5 per cent lignocaine.
Obese short woman, aged 44. Operation: subtotal hysterectomy for fibroids and appendicectomy, 18 ml of 0.5 per cent lignocaine and then sitting for 45 seconds.

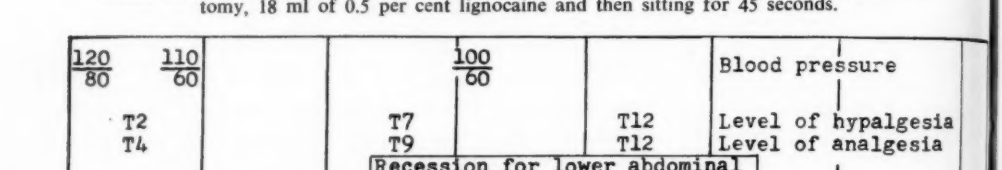

FIG. 4

A typical case of 1 per cent lignocaine.
Well-built man, aged 50. Operation: partial cystectomy for carcinoma of the bladder. 15 ml of 1 per cent lignocaine given in 15 seconds, the sitting position maintained for 35 seconds then the patient placed supine.

workers was confirmed, although the mean time for nearly full development of anaesthesia proved to be 7 minutes. Some further ascending hypalgesia and paresis was often observed for periods ranging from 10 to 30 minutes after injection. The zone of incomplete nerve block was usually extensive. For example, analgesia to the xiphisternum was sometimes accompanied by hypalgesia reaching the neck, but was unaccompanied by severe hypotension.

An important feature was the progressive weakening of the intensity of blockade upwards from the lumbar region. Motor block, which was nearly always complete in the hips and lower abdomen, was rarely perfect in the upper abdomen, no matter how steep the tilt, unless doses greater than 100 mg were employed. This may be attributed to a lower concentration of glucose than is present in the usual solutions of amylocaine or heavy cinchocaine.

Employing an average dose of 80 mg, anaesthesia was intense for a shorter time than was expected from the earlier reports on spinal lignocaine, quoted above. Recession commenced at the upper hypalgesic zone at 20 to 30 minutes after injection, giving an expectation of about 60 minutes analgesia for upper abdominal surgery and 80 minutes for the lower abdomen.

0.5 *per cent lignocaine.*

Owing to the rather uneven character of the anaesthesia obtained with 5 per cent lignocaine it was thought possible that a more uniform distribution of the drug could be produced by injecting a larger volume. Accordingly a 0.5 per cent solution in half normal saline was given and the experiment was justified but, although a more even anaesthesia resulted, motor block was less intense. The concentration of 0.5 per cent would therefore seem to be a critical one, only just below what is required for complete motor blockade. A typical case is represented graphically in figure 3.

Distribution appeared to be similar to that produced by 1:1500 cinchocaine when the Howard Jones (1930) technique is employed. In order to investigate the gravitational spread, 20 ml of solution at room temperature was injected in twenty-four cases, using a modified Etherington-Wilson (1934) technique, gradually allowing the post-injection time in the sitting position to approach that calculated on the basis of the formula: 5 × (T4 to L4 in inches) − 15 seconds. When the adult was kept sitting for 60 seconds instead of 70 seconds calculated from the formula, hypalgesia extended to the posterior scalp, and 45 to 50 seconds gave analgesia to the second thoracic segment with cervical hypalgesia. A wider distribution of analgesia than that with 1:1500 cinchocaine was also obtained when the volume was reduced to the standard 14 ml, and the more extensive spread is attributed to greater diffusibility of lignocaine.

1 *per cent lignocaine.*

In view of the finding that 0.5 per cent lignocaine was just too weak to give a complete motor block in all cases, a more concentrated solution of 1 per cent was tested on fifty patients. Better anaesthesia with good upper abdominal relaxation was obtained although the ultimate spread and the zone of hypalgesia were just as great, in spite of the smaller volume of solution injected. A typical case record is illustrated by figure 4. The mean duration of anaesthesia was similar to that with 0.5 per cent lignocaine, namely, 55 minutes for upper abdominal work and about 70 minutes for lower abdominal surgery.

When the preparation was injected in the lateral position more intense anaesthesia often resulted on the upper side and in order to exclude gravitational spread, fifteen patients were kept in the sitting position after injection for periods ranging from 10 to 60 seconds. The mean rise of cutaneous analgesia was four segments for 40 seconds sitting, that is the same as in the supine position. As might be expected, therefore, distribution was primarily by volumetric displacement.

Addition of adrenaline to lignocaine solutions.

No noticeable increase in the duration of anaesthesia was obtained by adding adrenaline to 5 per cent lignocaine hydrochloride and only a slight prolongation was obtained with the 0.5 per cent solution (table I). This was most disappointing in view of the prolongation and potentiation of the nerve block resulting from this drug in epidural analgesia (Stout, 1957). Prolongation with both cinchocaine solutions, light amethocaine and amylocaine was noted (table II). Delay in the onset of anaesthesia was slight but a consistent finding was that the blood pressure fall

was delayed by the addition of adrenaline to all the solutions tested (the figures for mean times of blood pressure fall have not been included here).

DIFFERENCES BETWEEN LIGNOCAINE AND OTHER DRUGS

All cases of upper abdominal anaesthesia received oxygen by a B.L.B. mask and facilities for augmented and controlled respiration were always held in readiness. Oxygenation was thus maintained whenever there was hypotension or ascent of the anaesthesia to the cervical segments. In all, six cases suffered transient loss of consciousness obviously attributable to hypotension, two under lignocaine anaesthesia. In one of these, lowering the gall bladder bridge promptly restored consciousness and the blood pressure to normal.

As distinct from interference with the function of higher centres by hypotension, fifteen cases (ten lignocaine, five amethocaine) showed evidence of cervical or cranial anaesthesia, and in order to avoid presenting lengthy case histories, their clinical features have been summarized in table III. Cervical and cranial anaesthesia were not encountered with other drugs.

Two principal conclusions have been reached by a study of these cases.

(*a*) *Action of lignocaine on motor fibres.*

In table III there is definite evidence of cervical motor blockade from lignocaine. On the other hand, prolonged unconsciousness from the upward spread of amethocaine arose in cases where there was no cervical motor paralysis. This supports the contention that lignocaine has a greater affinity for motor fibres than amethocaine.

(*b*) *Action of lignocaine on the higher centres.*

Three of the patients in table III who had paresis of the hands from lignocaine, appeared at first sight to be unconscious; the eyes were fixed and central, the pupils normal and the lid and conjunctival reflexes absent. Upon shouting loudly into the ear or on opening the patient's mouth, he moved his head and eyes intelligently and obeyed an order to open the mouth, as speech was absent. In one of the three cases sufficient motor power was present for the patient to whisper replies to questions. The two cases described in table III as having "apparent loss of consciousness" did not respond to shouting. Unfortunately they could give no account of subjective sensations during operation but it seems possible that auditory anaesthesia was more complete. Stovner (1957) described a case of retained consciousness and anaesthesia of the nerves of the posterior

TABLE III

Symptomatology of cervical and cranial anaesthesia

Clinical signs in 10 cases of cervical motor block from lignocaine (5% 1 case; 0.5% 1 case, 0.5% with adrenaline, 2 cases; 1%, 6 cases)

Clinical sign	Number of cases present	Duration in minutes
Upper limit of hypalgesia ophthalmic V	3	
Upper limit of hypalgesia maxillary V	1	25
Upper limit of hypalgesia mandibular V	1	
Upper limit of hypalgesia C2	5	50
Conjunctival reflex absent	3	
Auditory anaesthesia	5	
Sternomastoid paresis	2	40
Complete diaphragmatic paralysis (conscious)	1	20
Diaphragmatic paresis	5	
Complete paralysis of the hand	4	45
Paresis of the hand	6	
Apparent loss of consciousness (no hypotension)	2	10 & 18
Visceral traction pain	1	
Bradycardia	1	

Clinical signs in 6 cases of loss of consciousness from amethocaine (dosage range 8 to 14 mg of 1/1000).

Clinical sign	Number of cases present	Duration in minutes
Upper limit of hypalgesia ophthalmic V*	1	
Probable upper limit of hypalgesia C2–5	5	
Conjunctival reflex absent after consciousness lost	4	
Doubtful paresis of diaphragm*	1	
Slight paresis of hands*	1	
Upper limit of paresis thoracic	5	
Loss of consciousness	6	15, 35, 40 45, 180 & 300
Respiratory arrest (no hypotension)*	1	13

*The same patient.

fossa from lignocaine. Sykes (1958) reminds us that a low concentration of procaine is capable of anaesthetizing cerebral nerves whilst sparing consciousness, and it is clear from these cases that concentrations of lignocaine producing a cervical motor block and even phrenic paresis may leave consciousness unimpaired. It seems probable that amethocaine is different in this respect. Low concentrations produced loss of consciousness rather than anaesthesia of the nerves of the cervical cord or of the posterior fossa, although the latter cannot be excluded with certainty.

The action of lignocaine on visceral pathways.

The efficiency of blockade of the upper abdominal traction reflexes is extremely difficult to assess because of the necessity of differentiating vagal and phrenic sensations. Nevertheless, cases of lignocaine spinal anaesthesia showing paresis of the hand frequently developed retrosternal pain and nausea suggestive of the escape of sympathetic afferents. High blocks with cinchocaine and amethocaine were more often free of sensation during gastric surgery and this suggests greater sparing of the sympathetic fibres by lignocaine, in spite of a wider and shorter somatic motor block. Pethidine was found to be effective in relieving this complaint caused by visceral traction.

Intensity of vasomotor blockade by lignocaine.

In addition to the assessment of the activity of lignocaine, an attempt was made to substantiate a clinical impression which we have held for some years, namely that the hypotension is greater as the result of spinal anaesthesia with cinchocaine than with amethocaine. Any study of hypotension must be made with the greatest circumspection, as many factors are involved. The proportion of cases developing "very severe", "severe" and "moderate" hypotension was obtained for blocks above T6 and below T6 for each anaesthetic solution. For the high blocks the number of cases was generally less than forty, and therefore of little value. The proportion of patients having hypotension in the low blocks is given in table IV. No firm conclusions may be drawn from such few cases. The most that may be said is that it does not run counter to our clinical impression of the hypotensive activity of cinchocaine, and that lignocaine affects the vasomotor mechanisms certainly no more than and possibly less than other drugs. It was thought to be significant that four cases in table III with cervical motor block and an intense somatic block of the whole lumbothoracic region had no fall of brachial blood pressure as compared with the pre-operative level. In this connection it is doubtful whether high spinal anaesthesia with lignocaine would prove as effective as procaine in the induction of hypotensive anaesthesia.

TABLE IV
Incidence of hypotension

Solution	Number of cases with upper level of analgesia T7 or below	Per cent with very severe, severe, and moderate fall of B.P.
5% lignocaine	71	13
5% amylocaine	83	16
5% amylocaine plus adrenaline	92	24
1% amethocaine	43	21
0.5% cinchocaine	61	23
0.5% cinchocaine plus adrenaline	37	29
1/1500 cinchocaine	42	43

Differences of drug action in subarachnoid and epidural anaesthesia.

Because of interesting differences of drug potency in the two techniques, mean figures for onset, duration and intensity of motor block have been obtained for each drug used in this series of spinal anaesthesias and compared with similar mean values published in a previous paper on epidural analgesia (Stout, 1957). Drugs have been placed in order of potency in table V. Differences not accounted for by variations in dosage ratios are the longer duration of lignocaine compared with procaine and amylocaine, and the greater intensity of motor blockade compared with cinchocaine and amylocaine in spinal epidural analgesia, where diffusibility through connective

TABLE V

Comparison of drug potency in subarachnoid and epidural spinal anaesthesia

Mean dose in mg		Mean onset in minutes		Probable mean duration in minutes		Intensity of motor blockade
Subarachnoid spinal anaesthesia (1,107 cases)						
Cinchocaine	7	Procaine	6.2	Cinchocaine	148	Cinchocaine
Amethocaine	13	Amylocaine	6.7	Amethocaine	120	Amethocaine
Amylocaine	52	Lignocaine	7.2	Lignocaine	72	Amylocaine
Lignocaine	96	Amethocaine	7.7	Procaine	70	Lignocaine
Procaine	114	Cinchocaine	9.8	Amylocaine	63	Procaine
Epidural spinal anaesthesia (400 cases)						
Cinchocaine	77	Lignocaine	16.0	Cinchocaine	210	Amethocaine
Amethocaine	84	Procaine	16.0	Amethocaine	170	Lignocaine
Lignocaine	398	Amylocaine	17.0	Lignocaine	100	Cinchocaine
Amylocaine	525	Amethocaine	22.0	Amylocaine	80	Procaine
Procaine	541	Cinchocaine	24.0	Procaine	55	Amylocaine

tissue and especially through dura mater (Bromage, 1954) may greatly affect the nature and intensity of the nerve block obtained.

SUMMARY

Trials of lignocaine hydrochloride as a spinal anaesthetic were conducted with one hyperbaric solution and two dilute solutions, in a dose ranging from 25 to 150 mg. The drug gave an intense anaesthesia for a period a little in excess of amylocaine and procaine. The mean duration of anaesthesia was about 75 minutes. The initial appearance of paresis was often quicker than after the other drugs of the control series, but the time for full onset was similar, i.e. 7 minutes. The zone of incomplete block tended to be wide, maximum spread of solution occurring in 25 minutes. Recession then commenced at the hypalgesic segments. Thus the average durations of cervical, upper abdominal and lower abdominal anaesthesia were respectively, 20, 60 and 80 minutes.

The addition of adrenaline to lignocaine spinal solutions (5 per cent and 0.5 per cent) did not prolong anaesthesia to any useful extent.

Because of the wide spread of the drug, partial blocking of the trigeminal, auditory and accessory nerves was sometimes seen, and consciousness tended to be retained. Blocking of the phrenic nerves was not harmful provided oxygenation was maintained. Vasomotor blockade was, if anything, less complete with lignocaine than with other spinal anaesthetics since hypotension was limited.

The authors preferred the 1 per cent solution for upper abdominal surgery because of more uniform distribution in the areas to be anaesthetized and because of the certainty of adequate relaxation in the majority of cases. Distribution in the spinal theca was by volumetric displacement. Although 70 to 80 minutes anaesthesia could be obtained sometimes, the average duration of 55 minutes unfortunately limited the scope of upper abdominal surgery which could be performed under this anaesthetic alone.

The 5 per cent solution with glucose gave slightly longer anaesthesia and should prove more efficacious for surgery upon the perineum, the lower extremities, and perhaps the lower abdomen. It appears probable on clinical grounds that the 5 per cent solution with glucose may undergo loss of potency if stored in hot climates.

Lignocaine may prove to be preferable to amylocaine and procaine for its slightly longer action and possibly greater safety, as there is less hypotension. However, it cannot compare with cinchocaine and amethocaine as regards the duration of subarachnoid spinal anaesthesia.

ACKNOWLEDGMENTS

Our thanks are due to Professor Saib Shawket, Dean of the Faculty of Medicine, Baghdad, for kindly permitting publication of this article. We are indebted to Miss Leila Khattab, B.Sc., of the Government Chemical Directorate, for having analyzed Xylocaine samples and to Messrs. Duncan Flockhart and Company of Edinburgh for having kindly supplied all the ampoules of 5 per cent and 0.5 per cent "Xylocaine Hydrochloride", used in these clinical trials.

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BOOK REVIEW

Hospital Planning for the Anesthesiologist. By W. H. Dornette. Published by Blackwell. Charles C. Thomas, Springfield, Illinois, U.S.A. (Monograph). Pp. 119; illustrated. Price 40*s*.

This book gives a simple and straightforward account of the planning of an ideal hospital. It would provide a useful guide to an anaesthetist confronted for the first time with the problems involved in such an undertaking although circumstances and requirements in this country are rather different from those in the United States and financial resources are seldom likely to be on the same scale.

The author lays emphasis on two important points: firstly, designing in consideration of ultimate hospital expansion, and secondly, the importance of the anaesthetist taking his part not only in designing his own department but in the broader aspects of total patient care.

An adequate amount of detail, for the doctor as opposed to the architect, is given in most matters such as conductive flooring, illumination standards and alarum systems. Not much is said about the use of modern materials for theatre wall coverings. There are also some gaps in the account of the Central Service System. The layout and organization of such a system are dealt with thoroughly but the actual method of prepackaging is not mentioned and nothing is said about sterilization of anaesthetic equipment apart from syringes and needles. Apart from a mechanical conveyor system, which the author himself states is "very susceptible to mechanical difficulties", no other means of transport to and from the central supply is described.

Planning which involves adaptation of existing buildings is not dealt with but this could hardly be encouraged by a volume of this size.

The book is easy to read once the reader has become accustomed to certain transatlantic language usages such as "nursing station", "electrical outlet" and "location below grade". At least one word had to be referred to in the *Concise Oxford Dictionary* where, of course, it did not appear.

Noel Fenton

Brit. J. Anaesth. (1959), **31**, 182

THE APPLICATION OF A REGIME FOR THE TREATMENT OF NEOSTIGMINE RESISTANT CURARIZATION

BY

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Department of Anaesthesia, St. James's Hospital, Leeds

A NUMBER of cases of neostigmine resistant curarization have recently been reported in the literature (Hunter, 1956; Foster, 1956; Burchell, 1957). In the first and last of these series all the cases terminated fatally. In Foster's series two syndromes were described. In one there was delay of return of consciousness but not of muscle power; these cases recovered. In the other there was persistent paralysis and these cases ended fatally. Understandably all the cases reported were treated in a rather empirical manner and it is even possible that the treatment may have contributed to the final fatal result. An expectant policy has been advocated by Brennan (1957) and we have elaborated upon this idea and formulated a regime for the investigation and treatment of these cases.

Hunter (1956) postulated a persistent paralysis at the myoneural junction due to a potassium deficiency. Foster (1956) believed that there was a central action of curare and that in these cases of persistent curarization the relaxant penetrated the blood brain barrier. This penetration was facilitated by a low blood potassium level. Burchell (1957) suggested that there was a depression of the acetylcholine cholinesterase system and that the administration of anticholinesterase drugs would be ineffective in the presence of a very low cholinesterase.

The circulatory failure has probably been produced by:

(*a*) diminished venous return due to (i) venous stasis following muscular paralysis, (ii) intermittent positive pressure respiration;

(*b*) respiratory insults, allowing the patient to go for one or two minutes without aided respiration;

(*c*) administration of potent drugs without definite indications including (perhaps) cardiac and respiratory stimulants.

This syndrome has most commonly been seen in elderly patients subjected to emergency laparotomy for intestinal obstruction. For the last two years we have been careful in this type of case and used techniques avoiding the use of non-depolarizing relaxants. The following two cases occurred, however, in routine lists.

Case 1.

The first case which was anaesthetized by one of us (S.L.) was a rather obese lady aged 64. She presented as a carcinoma of the rectum for abdominoperineal resection. There was a history of chronic rheumatoid arthritis with marked kyphosis and joint deformities. She was not on corticosteroid therapy. Heart and lungs appeared normal. (Our normal technique for abdominoperineal resection is spinal anaesthesia with a covering sleep produced by light general anaesthesia. As the bony alteration of the spine would have made lumbar puncture difficult this case was anaesthetized by a technique based on the trial of Gray (1947).

She was premedicated with morphia 10 mg and atropine 0.6 mg.

At 11.45 a.m. anaesthesia was induced with thiopentone 400 mg, d-tubocurarine 16 mg and pethidine 20 mg. She was intubated with a No. 9 cuffed Magill tube after 4 per cent lignocaine spray (tube passed easily). An i.v. drip, 5 per cent dextrose in water, was set up. Anaesthesia was maintained with N_2O 5 litres, O_2 2 litres, using a circle absorber with absorption full on. Respiration was assisted.

At 12.10 p.m. the patient was placed in partial Trendelenburg (about 10°). Some protrusion of abdominal contents into operative field occurred. d-Tubocurarine 4 mg was given. Spontaneous respiration was still present and assisted.

At 12.50 p.m. relaxation was unsatisfactory. There was some "pushing" and gallamine triethiodide 30 mg was given. Spontaneous respiration disappeared. Full control of respiration was started. (The administration of gallamine following tubocurarine is, of course, open to criticism. It was felt at the time, however, that there was less likelihood of producing a persistent curarization at this stage by using a small dose of gallamine rather than further curare.)

By 1.30 p.m. the operation was nearly completed. Blood loss had been minimal, 750 ml of blood had been replaced. There was no sign of voluntary breathing.

1.40 p.m. Atropine 1.2 mg was given. Soda lime was removed from the circuit without respiratory response.

1.50 p.m. 2.5 mg of neostigmine was given over a short period of time, again without result.

2.00 p.m. It became obvious that this was a case of neostigmine resistant curarization, and the following plan of treatment was adopted.

REGIME

This was based on the concept of

(*a*) Maintenance of vital functions.
(*b*) Investigation.
(*c*) Specific treatment indicated by results of investigation.

(*a*) *Maintenance of vital functions.*

(i) Respiration was maintained with 50 per cent N_2O, 50 per cent O_2, using a mechanical respirator and a subatmospheric phase during the expiratory phase. A modified Beaver respirator (Burchell, 1957b) was used with CO_2 absorption. We feel that the use of a subatmospheric phase is essential, as the lowering of the mean intrathoracic pressure will help the venous return and postpone the advent of circulatory failure. The airway was kept clear with the aid of intermittent suction down the endotracheal tube.

(ii) The circulation was maintained by continuing blood transfusion. The blood pressure in this case remained stable at 120/80 mm Hg and no further treatment was needed to maintain circulation.

(iii) An electrocardiogram was connected and regular monitoring instituted.

3.00 p.m. Central diaphragmatic movements present but inadequate and the following investigations were carried out:

(1) Biochemical.
(2) Electrical: e.c.g.
Response to faradic and galvanic stimulation.

Biochemical. Serum potassium 3.9 m.equiv/l.
Serum sodium 122.5 m.equiv/l.
Serum chloride 98 m.equiv/l.
Serum cholinesterase 0.17 units (normal 0.75 units), estimated by Michel's method (Michel, 1949).

E.c.g. There was depression of the T wave and slight depression of S.T. segments in all leads. This was taken to indicate some potassium deficiency.

Muscle responses. Limb muscles showed normal response to galvanism but no response to faradism. Intercostal muscles showed a normal response to galvanism but no response to faradism. Faradic stimulation of phrenic nerve produced a strong diaphragmatic twitch. Thus, there appeared to be a peripheral muscular block in the normal differential pattern of curarization.

Treatment. Following on the e.c.g. interpretation:

4.00 p.m. A slow intravenous drip containing 3 grams potassium per litre was started. The e.c.g. monitoring was continued. No further neostigmine given in view of the very low cholinesterase value.

6.00 p.m. The e.c.g. pattern was now restored to normal. Respirations had become stronger but were still diaphragmatic only and inadequate. Whilst N_2O was discontinued for suction toilet the patient opened her eyes and showed signs of wakefulness.

7.00 p.m. N_2O discontinued. The patient opened her eyes and responded by slight movement of head to her own name. Respirations were still inadequate. N_2O recommenced.

8.00 p.m. Slight lower intercostal activity.

9.00 p.m. Good lower intercostal activity.

9.30 p.m. Complaining of pain. Morphia 10 mg given.

10.00 p.m. Normal respiration pattern. Assistance to respiration ceased. Given O_2 by mask. Fully conscious.

10.30 p.m. Transferred to ward. Patient made an uneventful recovery although convalescence was delayed by her arthritis. She needed a further anaesthetic for trimming of her colostomy later and was successfully anaesthetized on that occasion without any relaxants.

DISCUSSION

The interest of this case lies in the following factors. This was not an emergency case. It was the first to occur in our practice for over two years and during this time we have refrained from using nondepolarizing relaxants for ill patients with intestinal obstruction. There was no obstruction or ileus. There was no gross deviation of electrolytes. This case showed the same symptoms as earlier cases. There was no hypersensitivity and a normal dose was needed to produce curarization but the effect was not reversible by normal means.

A test dose, as advocated by Gray and Halton (1948) was not given. However, it probably would have revealed nothing because this was not a myasthenic type of reaction.

Opportunity was taken to elicit the site of block. The reaction to faradism showed a probable lower neurone block. The patient's return to consciousness before the return of adequate respiratory efforts precludes the acceptance of Foster's theory of penetration of the blood brain barrier and a central action of curare unless in this case one can postulate a specific action on the respiratory centre only. The potassium level was slightly subnormal as estimated by the usual method. The e.c.g. changes were enough, however, to warrant the use of potassium. This increased the amplitude of the diaphragmatic movement and led to better ventilation but did not affect the pattern of the paralysis. It also restored the e.c.g. to normal.

The mechanism in this case was probably a depression of the acetylcholine cholinesterase system. It is believed that a lesser amount of acetylcholine is produced, but as the cholinesterase value is low the action of the acetylcholine may persist longer than usual. The production of a complete block needs a normal amount of curarizing agent, indicating no abnormality at the receptors, in contradistinction to the myasthenic type of reaction. The prolonged effect is probably due to the slowness in building up enough acetylcholine to displace the curarizing drug. Anticholinesterase substances will have little effect in the absence of an appreciable quantity of cholinesterase.

Case 2.

The second case was a lady of 64 with a carcinoma of the rectum for an abdominoperineal resection. She was otherwise healthy.

Premedication was papaveretum 20 mg, hyoscine 0.4 mg. She was induced with 250 mg thiopentone and 50 mg suxamethonium and intubated with a No. 9 Magill's cuffed endotracheal tube after spraying with 4 per cent lignocaine. Anaesthesia was maintained with nitrous oxide and oxygen in a "closed" circuit with a leak and CO_2 absorption. Pethidine 50 mg was given in divided doses. After respiration was fully established and the suxamethonium presumably eliminated, 120 mg of gallamine triethiodide was given. This depressed the respiration and controlled respiration was instituted. A further 30 mg of gallamine was required before the end of the operation. One pint of blood was given during the operation to replace that lost. The blood pressure remained at a satisfactory level during the operation which finished 2 hours after the induction of anaesthesia.

During the half-hour following the operation the following measures were adopted to try to re-establish respiration:

Atropine 0.8 mg intravenously followed by neostigmine 2 mg i.v. Respiration was inadequate, central diaphragm only working.

Ten minutes later neostigmine 1 mg intravenously; no effect.

Five minutes later nikethamide 2 ml intravenously; no effect.

Five minutes later nalorphine 4 mg intravenously; no effect.

Five minutes later, patient hyperventilated with a Waters canister to eliminate supposedly toxic level of CO_2.

At this stage she was seen for the first time by one of the writers (G.B.B.). The blood pressure had dropped since the end of the operation and was now only 40 mm Hg systolic. The extremities were blue. There was gross peripheral circulatory failure. The patient was placed on a respirator with a sustained subatmospheric phase. A noradrenaline drip (4 mg noradrenaline in a litre of 5 per cent dextrose) was started. Further blood was infused. Samples of blood were then taken for biochemical investigation and an electrocardiograph connected. Within half an hour the systolic pressure had reached 100 mm Hg and the circulation had improved. In an hour the blood pressure was 110 mm Hg and there were no signs of peripheral failure. She was weaned from the noradrenaline but blood transfusion was continued slowly. A total of 250 ml of 5 per cent dextrose containing 1 mg noradrenaline was given and 2 pints of blood.

The respiratory picture was exactly similar to the previous case and similar investigations were performed. The results were:

(1) E.c.g. normal in all respects.

(2) Muscle reactions. Muscles reacted to galvanism but not to faradism.

(3) Blood chemistry: Na 127 m.equiv/l.
K 4.8 m.equiv/l.
Cl 110 m.equiv/l.
CO_2 combining power 24.2 m.equiv/l.

It was unfortunately impossible to have a cholinesterase estimation performed at the time. It was estimated the following morning and was normal 2.4 units (normal 2–4 units), estimated by Stedman's method (Stedman, 1933).

There was no further anxiety over her circulation and the respiratory muscles regained their power in a normal sequence but taking 7 hours after the end of the operation to return to normal.

For the last 4 hours consciousness returned each time the nitrous oxide was discontinued for more than a few minutes.

She made an uneventful recovery from the operation.

DISCUSSION

This case is of great interest, as it illustrates the ease with which peripheral circulatory failure can be precipitated in these patients by using drastic empirical methods of treatment. In most previously published cases peripheral circulatory failure has preceded death.

The two factors which reversed this process were (1) the noradrenaline drip and (2) the use of a subatmospheric phase in the respiration. The second is probably the most important as the blood pressure was maintained after the noradrenaline was discontinued. The site of the block was again definitely peripheral. If a cholinesterase estimation had been available at the time we would have given further neostigmine but without this information, preferred to adopt an expectant policy.

The aetiology in this case is not so clear, both potassium and cholinesterase being normal. The use of suxamethonium may have been a contributory factor. We feel that more clinical investigations of this type of case are needed to elucidate the problem, as it is doubtful if this very rare condition can be simulated in experimental animals.

SUMMARY

A regime for the treatment of neostigmine resistant curarization is described, illustrated by two cases each having a successful outcome.

The treatment is based on the theory that this reaction is due to deficient production of acetylcholine which may be associated with a low plasma cholinesterase. The abnormality is in the duration of the curarizing effect.

The regime is based on maintenance of circulation and respiration for sufficient time to allow enough acetylcholine to be built up and displace the curarizing drug. Potent drugs are withheld unless there is a specific indication for their use.

ACKNOWLEDGMENTS

We would like to express our thanks to Mr. D. B. Feather, Mr. H. S. Shucksmith and Dr. Carter for permission to publish these cases, to Dr. Goldie and his staff for their help with the pathological investigations, and to the Physiotherapy Department for the electrical reactions.

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THE HEAT MECHANICS OF THE WATERS CANISTER

Sir,—Dr. Ainley-Walker's article, "The Heat Mechanics of the Waters Canister" (January 1949) is a welcome contribution to the literature on this method of CO_2 absorption. By its simplicity and low cost the Waters canister has retained its popularity in face of growing competition from the circle absorber.

However, one or two of the conclusions drawn may be misleading. For instance, the statement that "the temperature of the inspired gas rarely exceeds that of the patient" may be true at the ambient temperature in which this series of readings was made, 76°F. Such a generalization may not be valid if one is working in a temperature of 80–90°F, which may be the common experience of many readers, either through poorly designed theatres, climatic conditions, or both.

It would have been interesting if the author had compared his results with those of some American workers. Clark et al. (1954) using a "to and fro" system, found their average temperatures to be 116°F in the canister, and 102°F in the gases passing into the trachea from the tip of an endotracheal tube. Burstein and Mark (1948) found inspired temperatures in the region of 104–113°F, when room temperatures were above 85°F, and suggested the use of ice as a coolant

Furthermore Dr. Ainley-Walker states that "no evidence has been found to suggest that the presence of a hot canister near the patient is in any way harmful, but rather the reverse", even though one of his patients appears to have been inhaling gas at a temperature of approximately 42°C (107°F). What effects were actually looked for in those cases in which the inspired gas temperature was above that of the patient? It would seem necessary to include studies on bronchial dynamics, ciliary movement, intratracheal condensation of water vapour, etc., before drawing such a conclusion, even if no gross disturbance was manifest at the time of operation. Similarly, observations on the temperature of the patients would have been welcome.

Was the writer entirely satisfied with the performance of the canister in the matter of CO_2 absorption in the clinical experiments? Figures as to the inspired CO_2 concentration would have been useful in assessing this. Robson and Pask (1954) have shown how easily channelling can occur in the soda lime when the canister is lying on its side, with diminution of efficiency and consequent drop in heat production. Did Dr. Ainley-Walker use their suggested modification to ensure tight packing of the soda lime when the canister was lying horizontally?

Fortunately overheating effects can, to some extent, be offset by utilizing a high flow rate of gases and Dr. Ainley-Walker has shown a significant decrease in the temperature of the inspired gases when the flow was increased from 1.3 l. to 2 l. per minute. However, I have recorded a temperature of 110°F within a canister despite a flow of 4 l. when the room temperature was 84°F, which suggests that the heat loss by this route is limited, if in fact one is to utilize exhaled gases to any extent.

L. J. DUNKIN,
Newcastle General Hospital

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ACTION OF THE AZEOTROPIC MIXTURE

Sir,—When a new combination of drugs is introduced into anaesthesia, it is important that anaesthetists should not be unduly influenced by reports from the laboratory which may have little bearing in the clinical field, and which may contain conclusions not well founded. We have in mind the paper by Raventós and Dee (*Brit. J. Anaesth.* (1959), **31**, 46), which appraises the value of the halothane-ether azeotropic mixture.

Having demonstrated that the small percentage of ether in the azeotrope contributes to its

anaesthetic effect, the authors proceed to a comparison, not between iso-narcotic concentrations of pure halothane and azeotrope, but between concentrations which contain *the same percentage of halothane*. Unlike Raventós and Dee, we have not been handicapped by lack of apparatus, since our colleague Dr. Epstein has constructed and calibrated an inhaler especially for the azeotrope. With this we have been able to use various vapour concentrations for clinical anaesthesia, and our impressions confirm those of others who believe that the azeotrope offers certain advantages over pure halothane, including a greater degree of freedom from depressant effects. Also, as would be expected, the azeotrope permits the use of a lower concentration of halothane vapour than when halothane is used alone. Work is in progress, but, as yet, we have insufficient data to bear statistical analysis. It is pertinent that Raventós and Dee themselves have not offered a statistically significant comparison, their only comment being that in their animals the relative changes in blood pressure and pulse rate are "about the same".

Some of the observations on the danger of explosion could easily mislead. The authors conclude that the lower limit of flammability of ether is approximately the same whether or not it is mixed with halothane. They then say that there could be a risk, therefore, of explosion when using the azeotrope in the higher concentrations needed for the induction of anaesthesia. Table I in their article shows that the lower limit of flammability of the azeotrope in pure oxygen is 8 per cent. We have seldom required, and never exceeded, a 3 per cent vapour of the azeotrope, in either oxygen or air. When increasing amounts of nitrous oxide are added, the azeotrope vapour concentration needed for induction falls correspondingly, and most clinical anaesthetists will agree that when the nitrous oxide in the mixture reaches 80 per cent (an example used by Raventós and Dee) unconsciousness will be produced without the addition of any azeotrope at all. In short, the laboratory data presented by the authors are irrelevant to the conditions of clinical practice.

It would be regrettable if this paper were to discourage anaesthetists from testing the value of a promising new mixture. One of several attractions of the azeotrope not mentioned by Raventós and Dee, is that the advantages of a halothane-like anaesthesia can be provided at a greatly reduced cost.

JAMES PARKHOUSE
B. R. SIMPSON
Nuffield Department of Anaesthetics, Oxford

DISPOSABLE RECIPIENT SETS FOR BLOOD TRANSFUSION

Sir,—Several types of plastic disposable blood-transfusion recipient sets ("giving sets") have recently been distributed to teaching and other large hospitals for use and comment.

As the representative of the Faculty of Anaesthetists on the sub-committee of the British Standards Institution which is considering blood-transfusion equipment, I would welcome any comments and criticisms regarding or suggestions for improvement of the disposable sets now in circulation. Perhaps readers who feel disposed to help in this way would write to the following address:

Department of Anaesthesia,
King's College Hospital,
London, S.E.5.

Information supplied would be regarded as confidential and passed on to the committee anonymously after correlation.

Yours etc.,

A. H. GALLEY
King's College Hospital, London, S.E.5

BOOK REVIEW

Cyclopropane Anesthesia (2nd edition). By Benjamin Howard Robbins, B.A., M.S., M.D. Published by Baillière, Tindall and Cox, London, 1958. Pp. xii + 293; figs. 74. Price 72*s*.

In this second edition of his monograph on cyclopropane Dr. Robbins presents what may now be regarded as a definitive study based on a considerable accumulation of experimental and clinical investigation. Even without the author's sustained advocacy over the years the general merits of cyclopropane are recognized by all who have taken the trouble to apply the careful and vigilant measures necessary for efficacy and safety so particularly enunciated by Waters in 1945 and Griffith in 1951.

Cyclopropane is explosive and, in certain circumstances, most of which are avoidable nowadays, disturbance of cardiac action may be associated with its use. These adverse features have been in the main responsible for its decline in popularity in some clinics, although a significant increase in the quantity manufactured appears to indicate that such a decline is not general.

Being primarily a pharmacologist the author has devoted much time to investigation of the cardiovascular effects of cyclopropane and quite appropriately by far the largest chapter deals in thorough fashion with the circulatory problems involved. Careful study of this well-documented section may readily create fresh interest in the agent and encourage its more frequent and more intelligent use.

In the reviewer's opinion this otherwise excellent monograph has been slightly marred by an attempt at a comprehensive but somewhat scrappy and seemingly hurriedly written description of too many relaxant drugs. It would have been sufficient and more appropriate to have dealt broadly with the principle of relaxation of muscle by specific agents in relation to modifications in the administration of cyclopropane as a general anaesthetic.

Prompting the foregoing criticism are the repeated misspelling of Professor Zaimis's name, the incorrect crediting of the first clinical use of gallamine with a variance in the dates in the text and in the list of references, and an untidy departure from alphabetic order on the last page of the bibliography. In a book whose second edition has just appeared nineteen years after the first, it is unfortunate that such errata, minor as they may be, may stand uncorrected for an indefinite period.

The format, illustrations and general production are of the highest standard and to all senior students, teachers and specialists in anaesthetics, Dr. Robbins's authoritative monograph can be highly commended.

John Gillies

WANTED

Copy of January/February and September/October 1957 "Current Researches in Anaesthesia & Analgesia" required.

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